N71-22026 to
N71-22038

NASA TECHNICAL
MEMORANDUM

NASA TM X-64575

SYSTEMS MANAGEMENT TECHNIQUES AND PROBLEMS

A Compilation of Selected Papers Presented at
Systems Management Conference (SM70)
March 31, April 1 and 2, 1970
Los Angeles, California

February 1, 1971

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (September 1968)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
TM X-64575		

4. TITLE AND SUBTITLE	5. REPORT DATE
SYSTEMS MANAGEMENT TECHNIQUES AND PROBLEMS	February 1, 1971
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR (S) Compiled by Scientific and Technical Information Division	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington D. C., 20546	13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Technology Utilization Division, Administration and Technical Services

16. ABSTRACT

This report presents selected papers from the Proceedings of Joint Professional Conference on Systems Management, sponsored by NASA and ASQC, March 31 and April 1 and 2, 1970, at Disneyland Hotel, Los Angeles, California. Papers describe history and trends of Systems Management, basic principles and caveats, and the nature of various public and private complex problems in need of systems approach for solution.

A bibliography of NASA Systems Engineering and Management documents is included.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Systems Management Systems Approach Systems Engineering Cybernetics	Unclassified - unlimited Samuel E McCrary

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	136	$3.00

MSFC - Form 3292 (May 1969)

FOREWORD

This report presents a selection of papers given at the Systems Management Conference held at Disneyland, Los Angeles, California, March 31 and April 1 and 2, 1970, which was sponsored by 12 cooperating societies and agencies shown on the cover page.

The original planning for this conference included publication of the proceedings in their entirety by the American Society for Quality Control, but because of circumstances beyond their control, that society was unable to arrange for such publication.

Nevertheless, because of their general merit for contributing to a more wide-spread understanding of modern management techniques, and their potential for application to future complex problems in both the public and private domains, these selected papers are being made available to the general public through this publication by the Technology Utilization Office, Marshall Space Flight Center, Alabama.

COOPERATING AND SPONSORING SOCIETIES

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SYSTEMS MANAGEMENT TECHNIQUES AND PROBLEMS

HISTORY AND TRENDS OF SYSTEMS ENGINEERING

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"I believe that this is our clear duty. Because we cannot do everything which an ideal treatment might indicate, it does not follow that we should not do what we may. It will mean a distinct effort along measurable new lines. It will imply assemblage, analysis, selection, synthesis in various ways, classification, coordination and the development of ways and means of detecting and setting forth what the mathematician might term systems of point correspondences between the two classes of material, scientific facts on the one side, human needs on the other. May we not anticipate one of the triumphs of the twentieth century will be the making of some effective progress toward the establishment and development of a science of the use of science." William F. Durand [1] in the Scientific Monthly, August 1917.

Introduction

Over half a century ago, William F. Durand cited the need for "a science of the use of science." During the past 3 decades, systems engineering has evolved as a proven methodology providing an orderly approach for the timely development of large complex weapon systems. The language of the "systems approach" has extended outward from the engineering world to become an important communication link between all disciplines and professions.

Study of the recent history and current trends of systems engineering can provide a basis for better understanding of what is systems engineering and how it can be used most effectively.

Systems engineering has expanded from a technique for the technical development and integration of black boxes to become a total system technical management process. Many elements of the process have been developed as individual modules or units; examples are system analysis, system integration, and technical data management. New techniques and tools currently are undergoing development and evaluation such as the System Engineering Management Plan (SEMP) and Technical Performance Measurement (TPM) systems.

The potential for the transfer and translation of systems engineering techniques to the socioeconomic world has been in a period of examination and evaluation since the "California Studies" were initiated in 1964.

Definitions of Systems Engineering. It is recognized at the outset that systems engineering is interdisciplinary in nature and that a specific definition has not been generally established and accepted. Further, the terms system engineering and systems engineering are often used interchangeably in the same document. Systems engineering may be defined as encompassing the following:

- An attitude or plan of action.

- The systematic application of many disciplines, tools, and human resources to identify and solve problems.

- A flexible approach (process) which requires development and design to meet the requirements and constraints of each new system program.

The Department of Defense (DoD) Military Standard, MIL-STD-499 (USAF), on "System Engineering Management" provides definitions of system engineering and SEMP. The SEMP adds (1) the technical program planning and control function and (2) the engineering integration function to the system engineering function. The resulting threefold function of a SEMP closely expresses the meaning of systems engineering as used in this paper.

MIL-STD-499 Definitions

System Engineering. System engineering is the application of scientific and engineering efforts to (a) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (b) to integrate related technical parameters and assure compatibility of all physical, functional, and program interfaces in a manner which optimizes the total system definition and design; and (c) to integrate reliability, maintainability, safety, survivability (including electronic warfare considerations), human, and other such factors into the total engineering effort.

SEMP. SEMP shall be composed of three major parts: (1) system engineering; (2) technical program planning and control; and (3) engineering integration.

A concise and still valid definition of the term was stated by Dr. Simon Ramo [2]: "Systems engineering — the invention, design, and integration of the whole ensemble, as distinct from the invention and design of the parts — is an always present part of practical engineering.

History

Overview of the Decades

1940-1950. A perspective of the evolving nature of systems engineering is provided in Figure 1. The top band shows that by 1940 the need for system engineering was recognized and applications were underway. A methodology was developed within major system-oriented companies to meet a function found to be required in the in-house research-to-production process. Technical aspects os system engineering were known to be important. However, tradeoffs related to policy making, contract type, and technical change activities as relating to an external program management agency (customer) were not emphasized in these early applications of system engineering. It is noted that this type of inhouse system engineering activity still has application today.

1950-1960. The second band of activities shown on Figure 1 indicates that in the early 1950's the defense industry was faced with the urgent and complex task of closing the missile gap with the initiation of the ICBM program [3]. Until about 1960, the basic contracting method utilized in ICBM contracting was based on the cost plus fixed fee (CPFF) or related type of contract which provided the contractors with relief from excessive financial burdens on high technical risk programs. A combined program management/systems engineering methodology was developed in the weapon system acquisition approach that permitted the customer to unify a number of contractors into one large program, controlled by the customer. The contractors had varied backgrounds of technical capabilities for product development (e.g., chemical, structural, propulsion, electronics, etc.) and differing internal management systems. This project-oriented methodology provided a means for the responsible Department of Defense agency to exercise a unified control of system engineering management and control over the contractor's internal management of subsystem design and development.

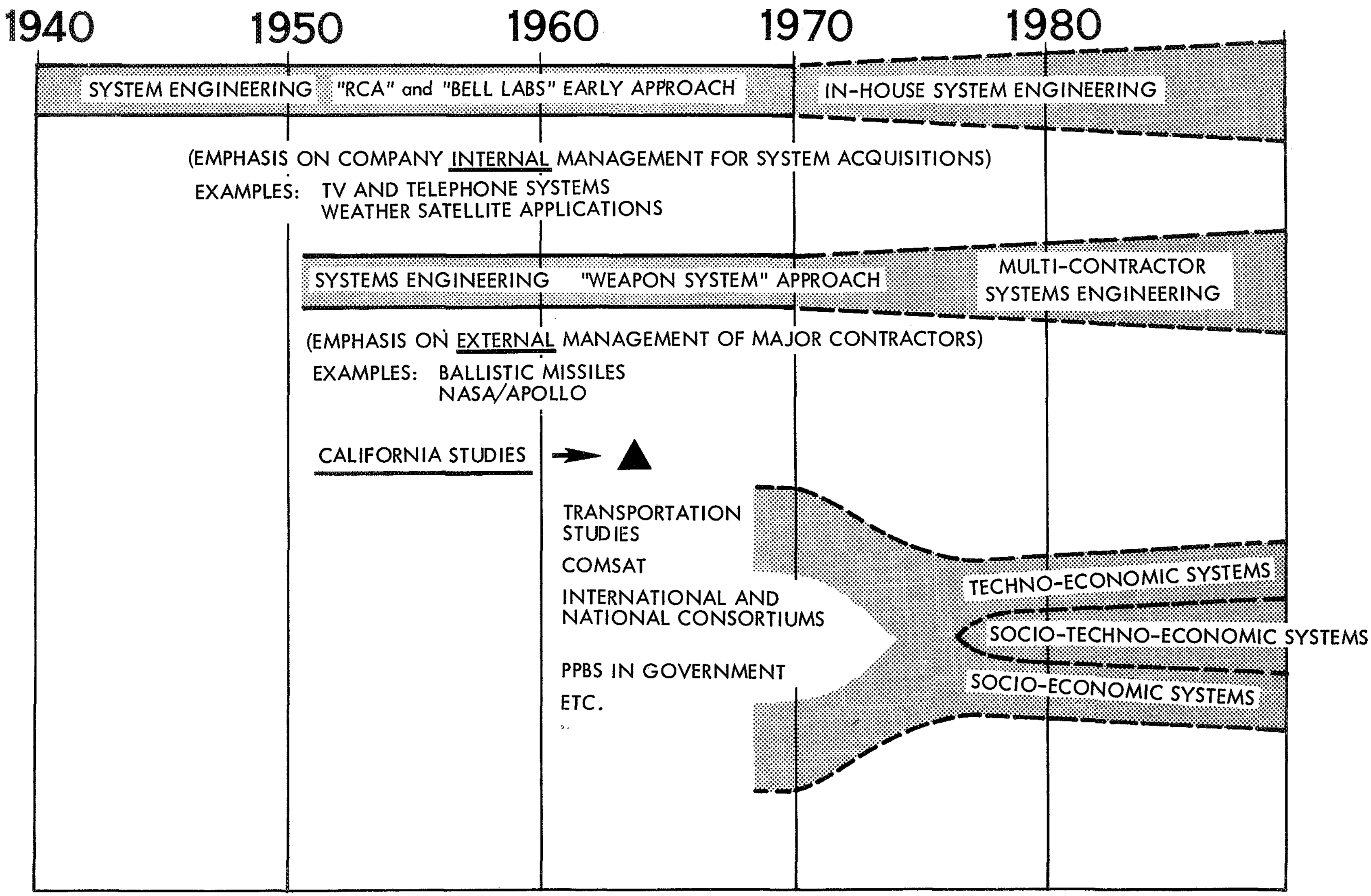

Figure 1. Evolution of systems engineering applications

1960-1970. Early in the 1960's, NASA initiated the Apollo Program which provided another systems engineering challenge to both government and industry. Again a program was required to integrate the complex technological capabilities required to reach the moon before 1970. Many of the systems engineering techniques developed during the preceding decade in support of the ICBM Program were transferred to supplement the Apollo Program as it was developed under NASA management.

By 1965, the much-discussed "California Studies" heralded a widespread examination and evaluation of the potential for the effective expansion of systems engineering methods and techniques to other government programs encompassing socio-techno-economic areas. The addition of another dimension of complexity represented by the "socio" area has required new thinking related to the applications commonly referred to as the systems approach. As indicated by the third band of Figure 1, the transfer and translation of Aerospace Technology into new areas is being examined and tested [4].

Significant Milestones. Because of the interdisciplinary nature of systems engineering activities, its history is strongly interlocked with the histories of the systems disciplines or elements that are integrated into the systems engineering process. A new systems engineering process is developed or tailored for each major program. Figure 2 identifies typical events and dates considered to be significant in the evolution of systems engineering. Figure 2 is indicative rather than comprehensive in nature. It is intended to provoke thinking on the part of the reader as to other significant milestones which also have had a direct bearing on the development of systems engineering over the past 3 decades. The significance of a number of these milestones is discussed in the next four subsections in which major discipline areas encompassed by the total systems engineering function are identified.

Systems Analysis Disciplines. Systems analysis has evolved from the basic engineering analysis practices of the past in which parametric studies were conducted to establish design requirements based on the results of tradeoff studies. Later, operations research techniques [5] were developed during World War II in response to military needs for a scientific method of providing a quantitative basis for decisions related to the management of controllable operations.

System effectiveness models relating reliability and maintainability to system availability developed during the 1960's provide a quantitative methodology for the evaluation of the effectiveness of a proposed or actual system in terms of selected measures, requirements, and decision criteria.

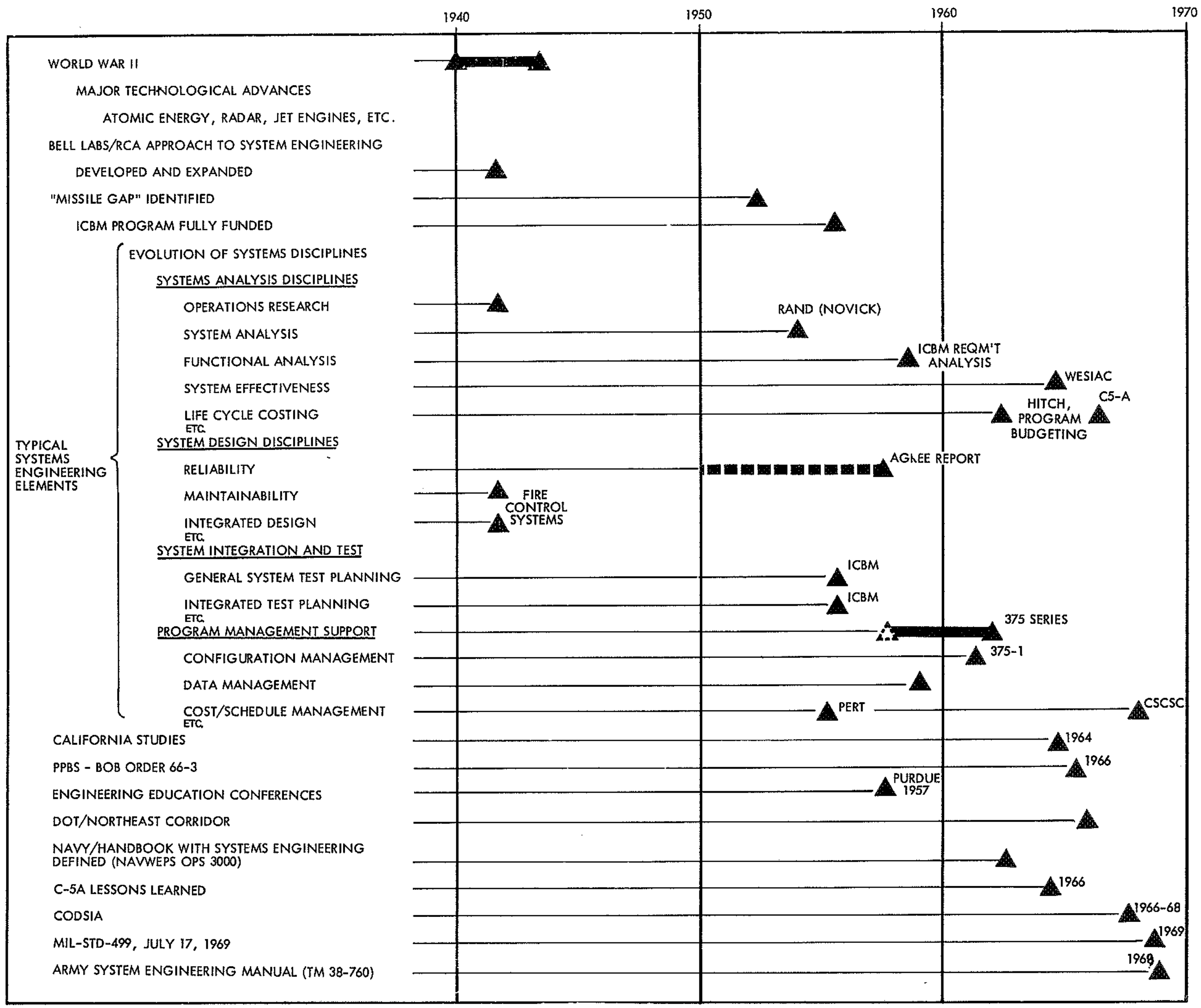

Figure 2. Significant milestones in the evolution of systems engineering, 1940 to 1970

Equations for effectiveness models are summarized in Reference 6 which includes reference to the Air Force WSEIAC model developed by the Air Force in 1964.

System Design Disciplines. System design activity is concerned with integrated design and tradeoffs associated with the optimization of the total system as distinct from detailed equipment design of the subsystems and components. It encompasses the systems' disciplines related to reliability, maintainability, safety, human factors, logistic support, and others. One of the more significant of the historic milestones associated with the "ILITIES" is illustrated by the history of reliability. Reliability engineering was developed during the decade starting in 1950 with two approaches. The first involved data collection and fact finding, principally the accumulation of failure-rate data through test programs. The second approach initiated the conduct of research to develop mathematical and engineering techniques to optimize the resolution of reliability problems. A major reliability milestone was reached with the development and issue of the AGREE Report in 1957 [7]. Many solid achievements in the field of reliability have been recorded subsequent to that time.

System Integration and Test. During the past decade, the importance of system integration activities has become widely recognized, and contracts for system integration work are quite common and no longer unique. System test is also recognized as a highly important area. A key factor which conditioned the ballistic missiles program from the very beginning was the emphasis placed on the development-test concept. Unlike an aircraft test program, ballistic missiles, once launched, could not be reused. Moreover, test facilities of the size and scope required for the accelerated missile program were virtually nonexistent in 1954. Consequently, a large-scale facility program had to be laid down, as well as one for production facilities. Insofar as possible, components were thoroughly tested on the ground prior to flight tests. A solid history of accomplishments in terms of system integration and test procedures, techniques, instrumentation, and facilities development has evolved during the past two decades.

Program Management Support. The project engineering activities of the 1930's and the 1940's have evolved into highly complex and sophisticated operations in the 1960's. Management systems received intensive attention during the 1960's. This subject is discussed in greater detail under the topic "Trends." The outputs of key systems-engineering-oriented management systems such as configuration management become forcing functions which are required to stimulate the systems engineering process and often produce significant impacts upon the systems engineering/program management relationships. Well planned and executed systems-engineering-related management activities provide the sound basis essential for the conduct of a successful program. It is an established fact that "eyeball-to-eyeball" communications are an essential element in program management support.

Education and Research. The field of engineering education has been severely buffeted during the past 2 decades by the impact of the systems engineering interdisciplinary approaches to the solution of complex technical problems. A comprehensive report from an early conference dealing with the definition of systems engineering and its implications relative to curriculums of schools of engineering was reported in 1957 [8]. In Reference 8, the deans of leading schools of engineering attempted to distinguish between systems engineering and operations research. They also attempted to define what courses with systems content should be offered to adequately prepare the student. During the past 10 years, the titles and content of courses offered in engineering catalogues have been changed significantly to reflect the systems related disciplines now taught and practiced.

During the 1960's and as a part of the Apollo Program, NASA gave full support to the universities in their development of new courses and facilities and in the financial support of graduate level students seeking systems-related engineering degrees. Hugh L. Dryden, as Deputy Administrator of NASA, understood and fully supported the university in its role in support of the space program [9].

DoD concluded in Project Hindsight [10] that for the systems studied, the contributions from recent (post 1945) research in science were greatest when the effort was specifically oriented as "applied research" and directed to support project needs.

Concepts. The following listing is typical of systems-oriented concepts which were developed and applied during the ICBM Program over the past 20 years:

- Definition of the program life-cycle.
- System-subsystem/interface.
- Concurrency
- Baseline management.
- Critical mix of capabilities.

- Feedback cycle of iteration of analysis and design data.

- Life-cycle costing.

- Flexibility combined with firmness in meeting objectives and requirements.

Space does not permit detailed discussion of the evolution and application of these concepts. However, it is important to recognize that application of concepts found to be valid at one period of time may be dependent on factors which may change with time. For example, concurrency concepts which may lead to planned redundancies in the development of major system components in times of stress, when budgetary considerations are secondary, may not be applicable as a concept during tight budget periods.

Trends

The identification of trends does not always provide a valid basis for forecasting the future, but it does provide a source of data to be considered in predicting future activities and events. With this thought in mind, the trends of systems engineering are discussed in the following three subsections.

Better Definition — Less Proliferation of Documentation. During the 1960's, the problem of the proliferation of management systems documentation became an excessive burden to defense contractors. For example, a contractor would have to be prepared to comply with up to 50 documents in developing his integrated logistic system for a special program. Regulations within the branches of the services were not standardized. In 1966, the Aerospace Industries Association published their findings on this subject. A government-industry approach to this problem was initiated in November 1966 by the DoD-CODSIA advisory committee for management systems control. The section of the final report on systems engineering/design critieria need/use analysis issued in March 1968 identified systems engineering documentation problems that required resolution and in addition found, "There is a general lack of censensus among all DoD components as to the definition of systems engineering, its scope, its relationships with other well-defined functional areas, and its role as a management tool versus its role as a technical tool." The results of the DoD-CODSIA study have done much to clearly identify existing problems. The recommendations are now being implemented. Greater emphasis is now placed on what is being sought as an end result rather than on how it should be attained.

Greater Effectiveness in Applications — Lessons Learned. A number of studies of the effectiveness of systems approaches have been conducted during the last decade. One of the better known "lessons learned" reports was prepared in 1966. It included examination of the effects of the application of the interim version of AFSCM 375-5 dated December 14, 1964, to the Total Package Procurement Concept (TPPC) on the C-5A program. The development of MIL-STD-499 by the Air Force and its present test applications is a direct result of that study.

Figure 3 shows a partial structure of DoD directives and instructions which define top-level defense policy relating to program and systems engineering management. Each of the services promulgates the official policy through a hierarchy of regulations, manuals, pamphlets, etc. Shifts in emphasis in policy or in implementation tend to take several years to become formally documented. However, informal communication is reflected in government and private magazine articles and other publications and in addresses by ranking officials. Symposiums and other sources provide increasing credibility to the evidence that the trend in current DoD policy places considerable emphasis on the improvement of many areas relating to both systems management and systems engineering.

Civil Systems Applications. Today, the term "systems approach" is used with a well-developed understanding throughout both government and industry. The need to conduct system requirements analyses and to divide major complex efforts into systems and subsystems with interfaces — all related to phases of the life cycle — is well established. The trends in the applications in the civil systems sector appear to center on the following:

- System analysis studies.
- Greater effectiveness in displays and the utilization of integrated technical data/information systems.
- Expanded capabilities of management control centers.
- Advancements in program planning and control techniques relating to life cycle analysis, work breakdown structures, integrated logistic support, and configuration management.

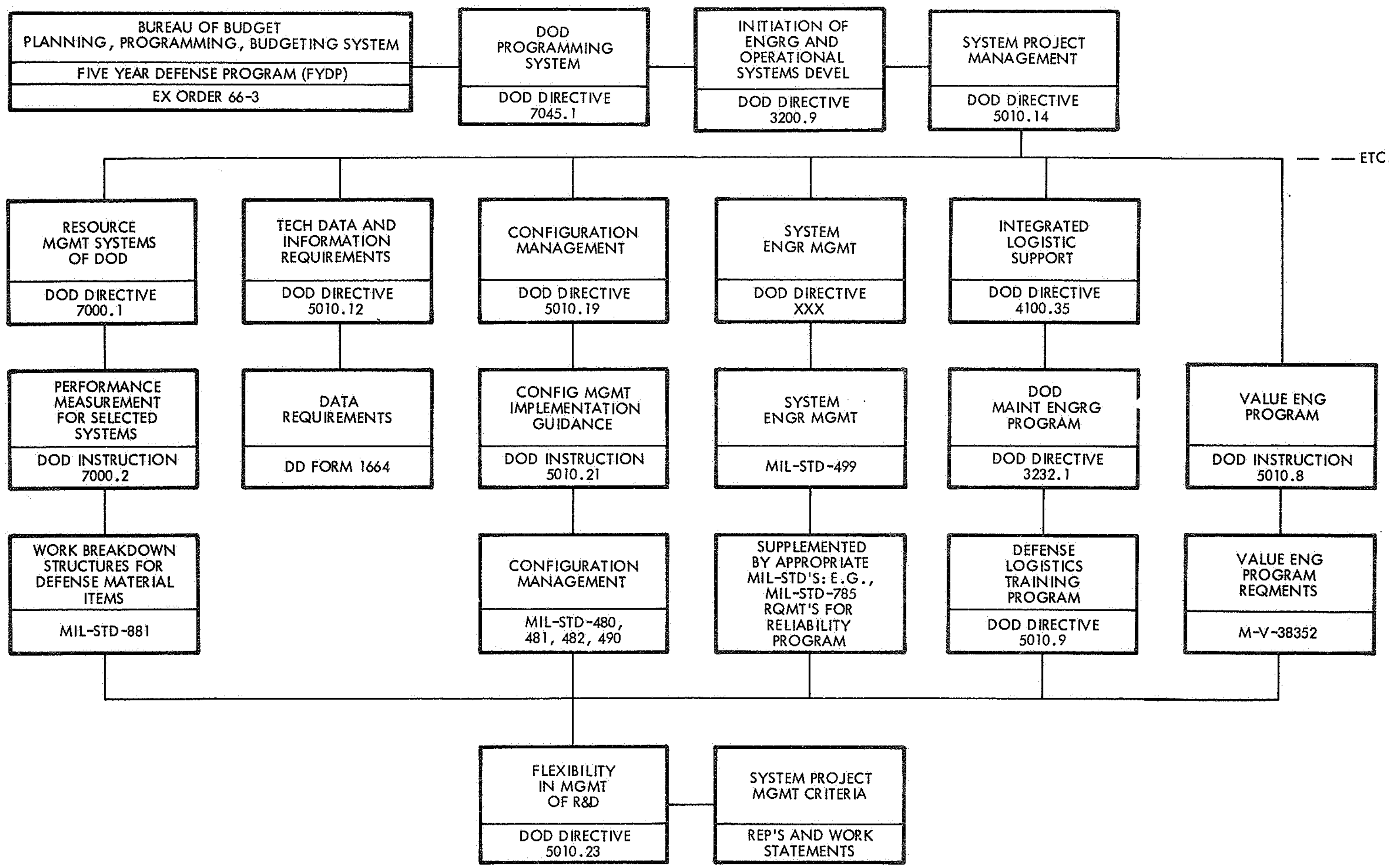

Figure 3. DOD requirements for systems management and systems engineering

Conclusion

During the past 30 years, systems engineering has evolved as an effective methodology and technique serving as a critical element in the technical development of large complex high-performance systems that have been completed within tight schedule constraints. Flexibility in adapting procedures (through innovation, transfer, and translation) combined with firmness in meeting objectives and requirements are two important characteristics that have contributed to the successful and effective applications of systems engineering. The trends continue for (1) the development of better understanding of the nature of the systems engineering process and for (2) the acquisition of additional experience in the application of systems engineering methodology as a factor in the civil sector of activity.

SYSTEMS MANAGEMENT AND COMMON SENSE

O. C. Boileau, Vice-President and General Manager
Missile Division, The Boeing Company

During the course of this conference, you are being exposed to many specific techniques and their utilization in systems management. At this luncheon let me share with you some plain, unsophisticated thoughts that I have on systems management and its techniques. I will attempt to convey the idea that systems management is disciplined common sense and that it is entirely dependent on you, the manager, for its creation and execution. Using two examples of techniques for coordination and planning, I will describe how common sense can be disciplined and elevated in scale. Further, I would like to challenge you to apply what you have learned here to the solution of problems outside the realm of DoD and NASA — problems that deal with today's social protests.

The conference pamphlet quotes the Air Force 375-series definition of systems management; that is, "the process of planning, organizing, coordinating, controlling and directing, organizations to accomplish, and objectives."

In discussing systems management as just outlined, we had better have a common understanding of the words "systems" and "management." The dictionary says a system is an ordered assemblage of facts, principles, doctrines, methods, procedures, parts, things, or others such as currency, heavenly bodies, and human organs. Management is the act of manner of accomplishing an objective. Since this program has a military and space genesis, let us confine systems to an assemblage of things, and management to the process of acquiring that system. Hence, as I define it, systems management is the obtaining of an assemblage of parts which achieve a specific performance objective.

Your attendance today indicates to me that you consider yourselves to be managers. I am sure each of you has a preconceived notion of what management is, but I suspect not many of you would agree. Further, my simple-minded definition of management is probably different from most. In my mind, management is change — change decision, change definition, and change implementation.

Management is not over-the-shoulder monitoring. Management is not bird-dogging every activity in the place to make sure it is going along o.k. I look at management as change, or, to put it very simply, if changes are not defined and executed in our operations, we, as a class of workers, are not needed — we can go home. Further, when I use the word "change," I mean any deviation from the current status that requires management action. It could be the definition and start up of a new program, or the realignment of a program that is departing from norm and exceeding predetermined, planned limits. The most well defined systems management plan in the world will result in chaos if we managers fail to play our proper role. If your program is moving down the road according to plan, don't get in the way until something needs to be changed. When a change is indicated, then apply your management expertise to effect the necessary adjustments. Manage by exception. Now, let us expand our definition of systems management by expanding planning, coordinating, and controlling and directing. I'll leave organizing to you for your unique situation.

Systems management is something we all do at one time or another without consciously recognizing that we are. As Simon Ramo put it in his book, "Cure for Chaos," and I paraphase, the systems approach is doing things right as against wrong, being intelligent rather than stupid, being objective rather than irrational. I would add that, the difference in calling it "systems management" rather than common sense is doing it professionally on a large scale.

On the small, everyday scale, consider that your objective is to buy an automobile. You weight alternative outputs versus input resources required. You mentally compare make and model, new or used, with the dollars required (on hand or to be financed) for the basic purchase plus licensing and insurance fees. You decide where to purchase (which dealer) and when to purchase it to fit your financing and travel requirements. You can complete my example in your own minds. The laying out, step by step, of these series of trades is program planning. This planning, plus the execution of the plan, is program management. The information you gathered and the decision criteria applied is the management information system.

The breaking of your objective into a series of trades is analysis. A large number of trades, bunched together by a common objective, is systems analysis. The acquisition of the funds and their repayment or replacement is resource planning. Your bank records are your cost control system. All of these are elements of systems management. If you do all of this successfully, you have achieved your objective with good job performance compared to the original plan. All that I have just described can be done in your head or on scratch paper. However, when your objective grows in complexity to a point where this process cannot be carried in your head, formal program planning and execution become necessary. This is systems management. It is particularly important if that objective has never before been obtained, such as a lunar landing.

To sum up what we have said, planning is the definition of all the related tasks with their necessary resources — people, time, money, materials, and capital assets required for each task leading to defined outputs with an identified recipient of these outputs. The management information system is the predetermined data and decision logic to be used to monitor performance against the plan and dynamically react to variations from the plan. Again, you as managers react only to the exceptions or changes to the original plan.

Naturally, program planning presumes there is a program. A program is something which has a clear-cut, well-defined objective, the same as a system. The objective of the Apollo Program was to make sure that Neil Armstrong and his fellow astronauts not only got to the moon safely but that they also returned safe and sound. Let's take a look at that program, Apollo, where systems management was applied very effectively.

Back in the spring of 1967, Boeing entered into a contract with the National Aeronautics and Space Administration to provide technical integration and evaluation (TIE) of the Apollo Space Program. The management activity was called "Apollo TIE" and involved integration of the total launch vehicle and the three modules of the Apollo spacecraft. "Management by exception" provided the baseline for design of the Apollo TIE. There was no other way to go. This room wouldn't hold all the paper generated on the Apollo Program. We had to get at the specific problems, with the right people, so that go/no-go decisions could be made within minutes. The right people, as it turned out, were scattered over most of the country, from Seattle to Washington, D.C., and across the Southeastern United States. The need to communicate effectively — coordinate in our systems management definition — with all concerned locations resulted in the development of a system called the blue network or the blue-net.

Blue-net was equipped to provide simultaneous teleconferences at locations in Seattle, Washington, D.C., Huntsville, New Orleans, Houston, and Cape Kennedy. Up to 250 managers have been on the system at one time. Each teleconference room is similar in layout, using three side-by-side, rear projection screens. The problems under discussion are projected via view foil projectors on the screens at each location with voice communication linked to open microphones and speakers at each location. All transmission is by telephone. This system was selected over closed circuit TV which was five times as expensive. Now we had the disciplined communication system and a good plan for using the system. The plan was developed to look at exceptions only and to solve them — coordinate, control, and direct the organization. Managers were given as much visibility as possible and made their decisions based on the data available. An example of this kind of management occurred on Apollo 10. Three days prior to launch of Apollo 10, we advised General Phillips that the TIE Management Information System had identified the acceptable risks (about 25) and that we considered Apollo 10 ready for launch. We also advised General Phillips that we would continue to work the open items and the 25 acceptable risks right down to launch time. This kind of experience indicates the dynamic side of the management process. You need good data, accurately and simply stated, to make the kind of decisions that were made on Apollo. The risks you take in your business may not potentially endanger lives, but the same principle applies, your decisions will only be as good as your information system. The management information system usually includes such subbreakdowns as: technical performance monitoring and control; schedule control; cost control; and resource planning. The original creation of the plan is the most important in my view.

It is most important because you have the highest leverage on good performance during the planning phase. A well-conceived initial plan avoids many costly changes. That "one small step for man" announced by Neil Armstrong when he started his moon walk may have seemed simple enough but the process that got him there was very challenging from a systems management standpoint, and would not have been possible without fully applying the planning, coordinating, controlling, and directing of systems management.

Another technique you may find useful in planning and controlling your job is an event logic network — a helpful tool in setting down your tasks in logical order. Visualize a pert-like network banded horizontally by doer, both internal and external to your control, with time as the horizontal axis.

We then have on the left-hand axis the various organizations, listed from top to bottom by level of authority, with the horizontal axis showing calendar time — not necessarily linear. On the field of these coordinates, start to place events which signal completion of a task. For example, mailing the check to the automobile dealer for payment on your car. That is a completion event taking no longer than 60 seconds for completing the activity of funding your automobile purchase. Now a question that must enter your minds is: "Are you going to mail that check before or after you drive the car?" If after, "How much after?" What data do you accept as a measure of satisfaction on your part of your new automobile's performance? From this short discussion you begin to see the development of a whole series of activities to be completed by some event that need interrelated data for satisfactory completion.

This is the rudimentary beginning of event-logic planning, with you as the customer and the automobile dealer as the supplier. Now relate this simple example to putting a man on the moon. In the same field, NASA as the customer must award a contract for first-stage engine development and delivery, award the lunar module and take these deliveries, make decisions on earth orbit (manned or unmanned), lunar fly-by missions (manned or unmanned), and so on. In answering these questions and deciding on the necessary input resources, including data from related activities, and interrelationship of all of the outputs, is in fact the planning process. Putting them on paper, in the form of this event logic network, assigns responsibility and forces planning decisions from the cognizant individuals — the organization — in the execution of the job.

Looking back on our experience at Boeing with this kind of planning, we developed our first event logic network on the Minuteman Program in 1962. We gathered key managers together from all departments (about 40 people) in a room about 100 feet long and 12 feet wide. The walls were, in effect, magnetic blackboards, which simplified changing plans as we moved along. Figuratively locking up these men forced all of the issues and knotty problems out into the open where they could be resolved. This group developed a top network containing 20 events of major importance and many more subsidiary events. The series of meetings took about 30 workdays, at the conclusion of which we invited our Air Force counterparts to review the program plan we had developed. Upon their concurrence, we proceeded with implementation of the Minuteman II Program. The amount of procrastination and confusion, normally a part of any complex program, was reduced to a minimum, we feel, largely because of the use of this type of management planning.

Moving on from the program planning to the actual execution of your plan, it is important to visualize the relationships that exist internally and externally between the coordinating, controlling, and directing functions that hopefully will get you to your objective.

Gen. John Chandler has already talked to you about formal systems management from a military standpoint. I would like to comment briefly about systems management from my standpoint as an involved individual.

The systems management approach should provide a sound business basis for the development of the best possible products at the most reasonable costs possible. However, if the contracting technique forces us into a position where we have to resort to gamesmanship, we all lose — you and I as taxpayers lose, and the national defense of the country is jeopardized.

I think the accusations and counteraccusations which have been voiced by industry, the military, and the government in recent months should serve to remind us that managing systems development is of itself a developing art. You are participating for these 3 days in a learning experience that will produce better systems for all of us. I am encouraged with the progress that is being made on recent contracts to provide contracting instruments during the research and development phases that allow for the unexpected. Some relief is coming with respect to simplifying the documentation of our program progress. The total evolution of the systems management approach is one of change and development. Our survival as a nation will depend to a large extent on our ability as managers and responsible citizens to adapt to change. It is no secret to any of us that the road ahead, politically, socially, academically, and within the community, is all up hill.

We are being tested as a nation from within to a point where our nation's defense seems almost unimportant to the average American. There is little reason to believe the current process of protest and violence will decrease in the future. We all live and work within the business, academic, and military institutions whose very existence is being challenged. Because of this, I wonder if we managers are contributing enough of our knowledge and experience to the solution of our society's problems. We are confronted with problems that require better visibility, better definition, and some kind of step-by-step plan for resolution; problems that are the responsibility of city, county, state, and/or federal governmental agencies.

However, I believe that before we can apply military and space systems management expertise and experience, some action is required by the governmental customer to bring about a market mechanism for the other executive departments, such as housing and urban development, health, education and welfare, and department of transportation, like the mechanism which exists with DoD and NASA.

The challenge of SM-70 could very well be a systematic management approach to finding solutions to the ever-increasing internal problems facing our nation. I don't know if that is what Neil Armstrong meant by that "one giant step for mankind," but that is certainly a worthwhile objective.

Gentlemen, I have discussed systems, management, and systems management, with the heaviest emphasis on management — on you! Nothing happens unless you bite the bullet. Make a decision — make a change.

SYSTEM ENGINEERING ARMY STYLE

Joseph M. Rockhind
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The Department of Defense tells us system engineering is the application of scientific and engineering efforts to:

1. Transform an operational need into a description of system performance parameters and a system configuration through the use of an interactive process of definition, synthesis, analysis, design, test, and evaluation.

2. Integrate related physical, functional, and program interfaces in a manner which optimizes the total system definition and design.

3. Integrate reliability, maintainability, safety, human and other such factors into the total engineering effort.

Armed with this approved definition, the Army Materiel Command (AMC) set out to develop a detailed procedure for system engineering — Army style.

The Army was not alone in undertaking such an effort. The Air Force and Navy were also active, and industry had been using the concept for quite a while. Effects of the Air Force activities have been studied by the Council of Defense and Space Industry Association (CODSIA), and its report provided sound advice for changes in application.

After about a year of arduous, concentrated effort, a specially trained Army team, assembled by AMC, produced Technical Manual 38-760, a comprehensive document entitled "A Guide to System Engineering." To gain acceptance by both industry and government, the manual is being retained in draft form while the American Ordnance Association (AOA), CODSIA, and Army agencies get the opportunity to help refine and finalize it for use.

Why System Engineering

There were many reasons for the introduction of system engineering into the weapon acquisition process. Time-honored techniques had not worked — a fact made painfully clear by Congressional Committees and the nation's press. Early cost estimates bore little resemblance to the final price tag for major weapon systems and completed systems left much to be desired in terms of maintainability, reliability, safety, supportability, and compatibility with interfacing systems, equipment, personnel, and facilities. It is the intent of system engineering to provide the improvement needed in these and other areas.

The scientific approach of the system engineering process (SEP) methodology can be described using the basic portrayal of the process shown in Figure 4.

This portrayal can be modified to introduce as many additional blocks or steps as needed to clarify and attain the desired objectives. Of the many possible portrayals of SEP, the Army has adopted a function analysis concept.

Given a set of input data consisting of mission requirements, operational environment, constraints, and measures of effectiveness and having access to a fund of knowledge from experience and research results, one arrives at the initial step of the SEP — function analysis. This step identifies the functions, and their performance requirements are established. For the time critical functions, a time-line analysis is also conducted.

The second step (Fig. 4) of the SEP in synthesis or conceptual design is reached. This is the point at which engineering technology is brought to bear in the creation of a design approach to meet stated function performance requirements.

The first "or" gate in the process following synthesis and leading back to function analysis highlights the close, highly interacting and interdependent relationship of these first two steps of the process. An evaluation and decision step is required any time alternative functions and/or synthesis solutions are evolved. These are usually subjected to tradeoff studies which should provide the basis for selecting that combination of system elements which achieve an optimized balance among performance, schedule, and total system life cycle costs, rather than an undue engineering sophistication of any single system element. Paramount considerations in the evaluation and decision step are control of costs and achievement of simplicity.

Evaluation leads to one of the following decisions which:

1. Selects a recommended system configuration.

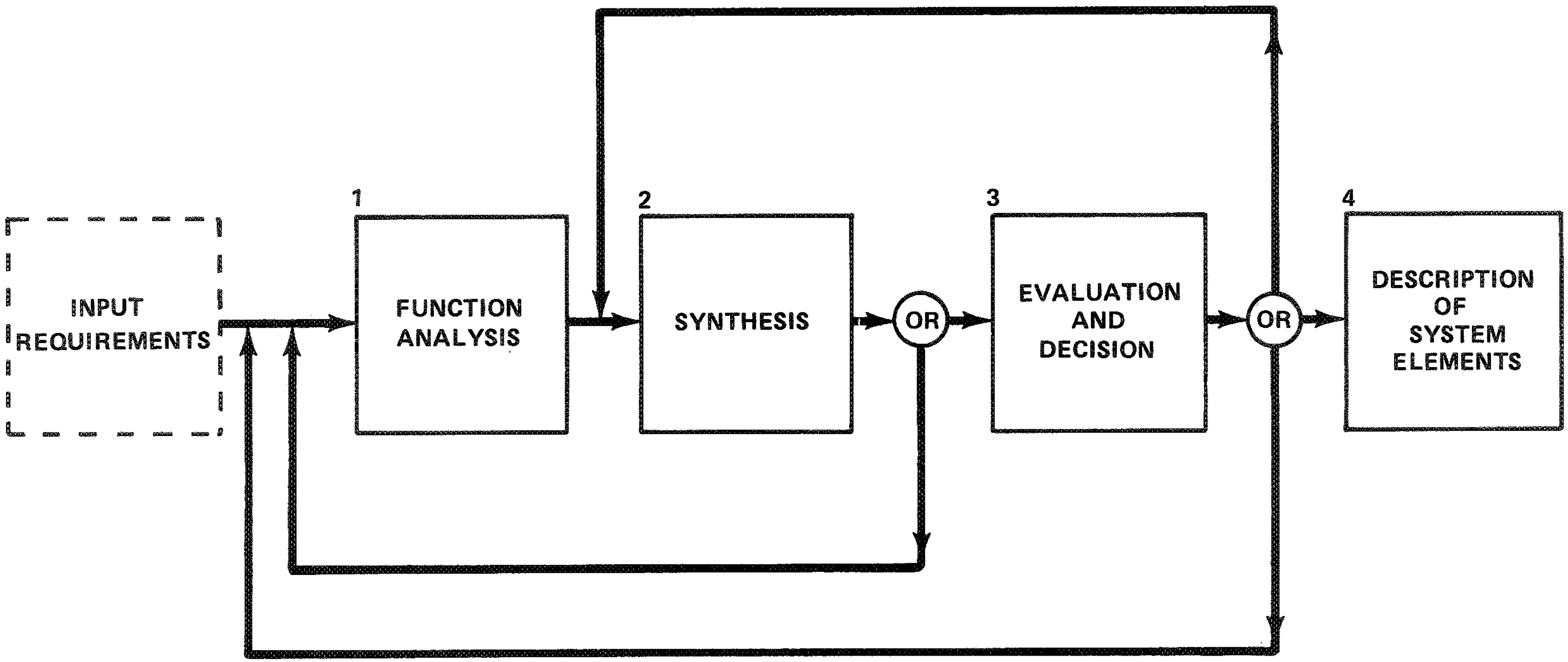

Figure 4. The system engineering process

2. Determines that additional analysis, synthesis, and/or tradeoff studies are required to make a selection.

3. Establishes that the state-of-the-art in technology does not provide an acceptable solution.

The decision determines the path after the second "or" gate shown in Figure 4. Assuming that a recommended system configuration is selected, the fourth step of the process (description) follows. The description step produces engineering data that define configuration, arrangement, and usage of all system elements. These data represent the system in terms of the functions identified, the performance requirements associated with the functions, the configuration and arrangement of system elements and techniques for their usage, and the effectiveness of the system elements in achieving functional performance.

Iterative Application

The Army applies the process to the areas shown at the top of Figure 5. Starting with performance requirements in the operations area, descriptions are developed for the systems elements listed at the bottom of the chart. An often-neglected element included in many Army systems is the "animal." Troops in Vietnam have used dogs, geese, and pigs to warn of the presence of a hidden enemy. NASA has used mice, monkeys, and chimpanzees in early space shots. As early as World War II, the lowly bat was investigated for use in a fire system. Other species are used as vectors, detectors, or messengers.

Continuing the analysis of the functions of the system in Figure 5, performance requirements and descriptions are developed for the other listed areas as they relate to the operational role and mission of the system.

Figure 6 depicts the application of the process to the various functional areas by cycling through interactions to evolve descriptions of the system elements. These descriptions are used as input to various plans used by the Army during the life-cycle management of material. Again, this begins with the operation cycle because, if there were no operations functions to be accomplished, there would certainly be no need for a system.

When equipment is synthesized, maintenance, support, test requirements, etc., are analyzed. This activity could be described as a helix tying together the functions performed by the total system.

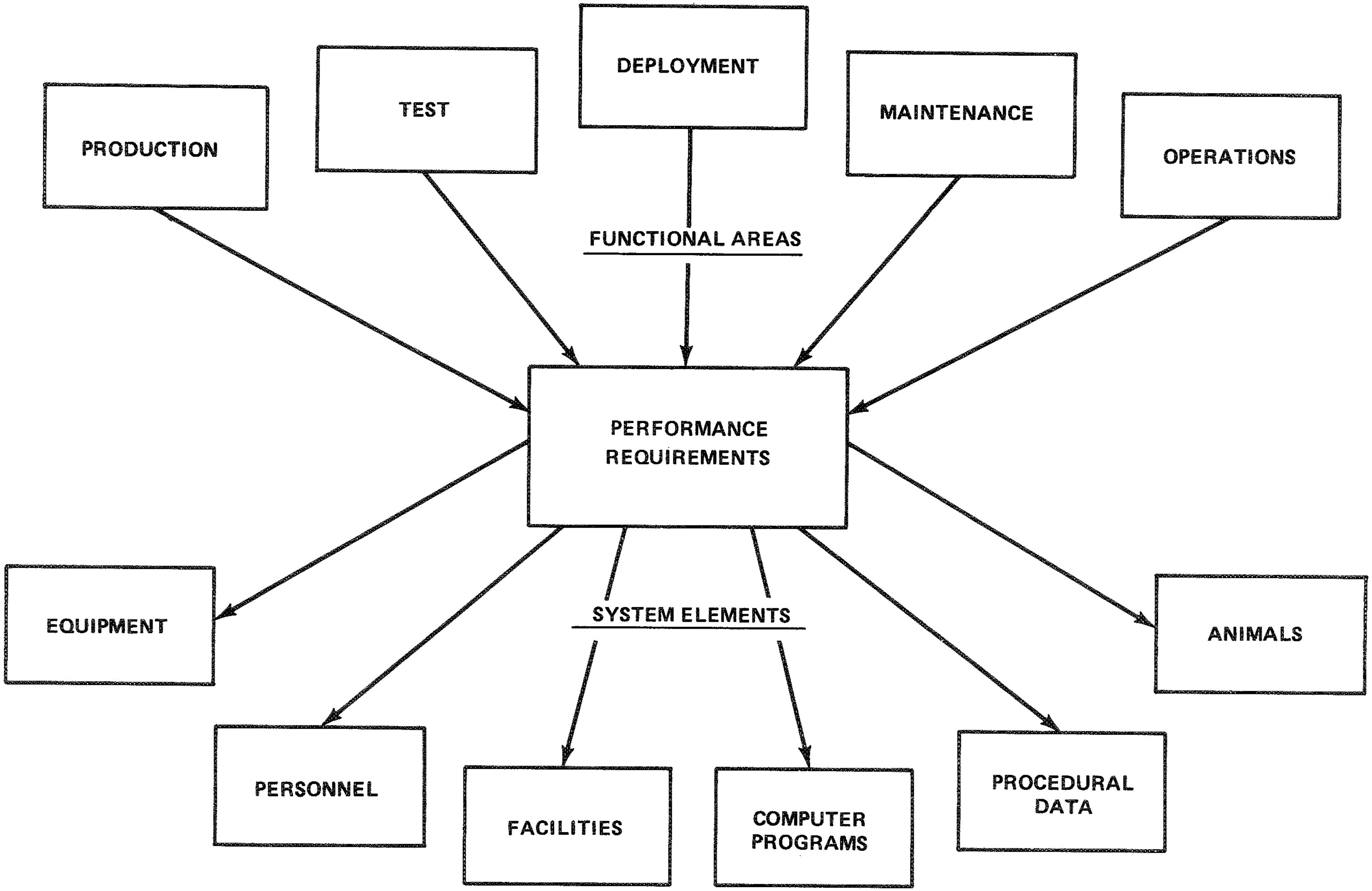

Figure 5. Source of requirements for system elements

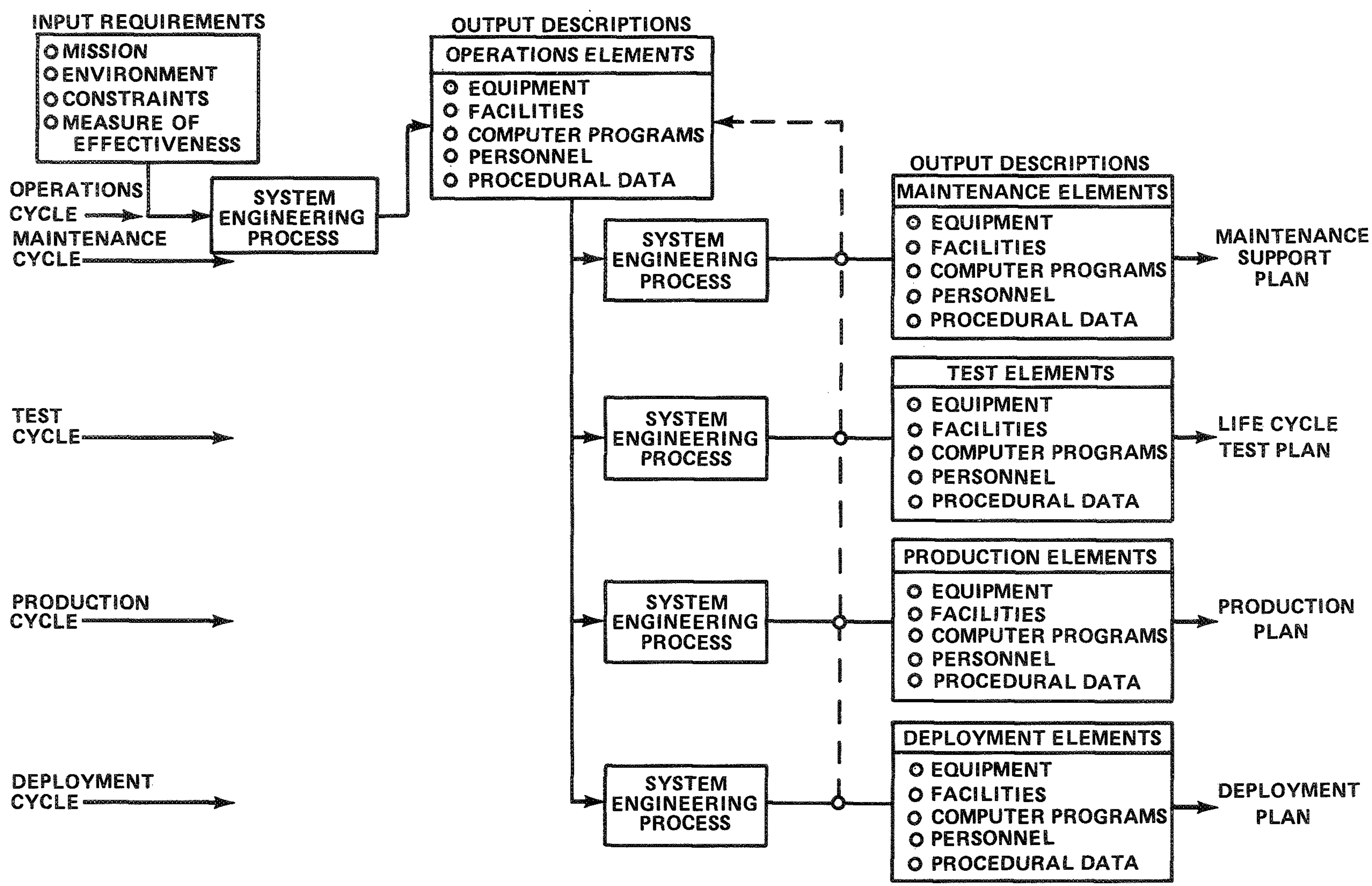

Figure 6. The application of SE process to functional areas

The Manager Versus the System Engineer

System engineering will not displace management; rather, it is a tool which strengthens the manager's hand and provides him the technical visibility required for sound engineering judgment. Relative roles of the manager and the system engineer are shown in Figure 7. Management will be dependent upon the information provided by system engineering and the application of SEP. Decisions regarding costs and schedules will be made after the results of technical performance measurements are considered. The work breakdown structure will be defined and the depth of WBS levels required will be established. There is a definite demarcation between management and system engineering, a line that must be delineated by management. Management must designate the type of decisions the system engineer will make and clearly record this authority in the management section of the SEMP.

For the purpose of consistency and further guidance, the Army has correlated system engineering with the life cycle management model for Army systems. The concept is applied for illustrative purposes to a project-managed system and includes a fullscale contract definition phase with development and production accomplished by industrial contractors. A narrative description (TM 38-760) of each block in the graphic flow of the model provides additional continuity, comprehensibility, and clarity to the model.

SEMP

For the Army to assess the likelihood of success of system engineering, it must examine a contractor's capability before he starts his design efforts. The Army needs to know how the contractor will implement the requirements and objectives of system engineering and expects his proposal before the start of Phase I-B of contract definition or its equivalent.

The plan should set forth the contractor's logic or methodology. Since he is going to tailor the process to the project, the Army will want to know what will be omitted or added. It needs assurance that the documentation internal to the process and that consisting of deliverable both is captured, controlled, and systematically identified. Other aspects of his plan would also affect the confidence to be placed in the performance of system engineering. It would indicate who makes the decisions and the limits of his authority. Fundamental to the concept is technical performance. The Army must know how the performance of a system can be predicted and what actions must be taken to assure that required performance will be achieved within the time-frame and costs previously estimated. This aspect is probably most critical to the success of system engineering in a development program.

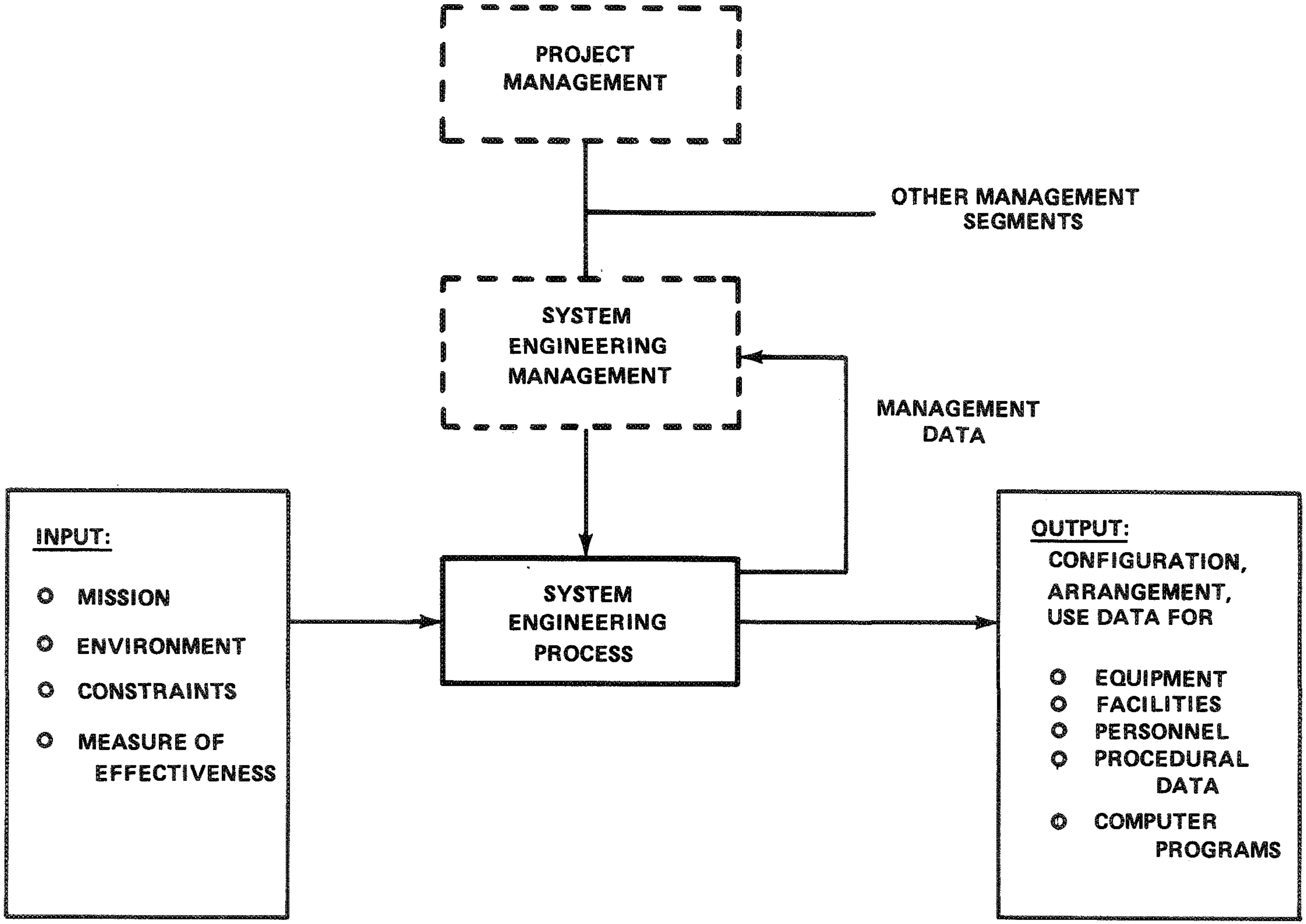

Figure 7. Role of the system engineering process

SEMP should also explain how the associated engineering disciplines will be integrated into the design of the system. The Army must know if the contractor has system engineering capability within his organization of if he intends to subcontract for it or accomplish the effort by use of consultants. If accomplished totally in-house, it is necessary to know the intercommand and interagency agreements that are to be made. Assurance would be needed that all supporting management systems had been taken care of and that adequate provision had been made for testing the performance of segments and components of the system.

From the Army's view point, an important element of SEMP is the time-phased schedule for the conduct of system engineering. For planning purposes, it is important that the Army know when the effort is to begin, what its progress will be, and how far into the life cycle management model it will project. While the Army recognizes that the bulk of the effort will be in contract definition, it anticipates there will be some system engineering effort throughout the life cycle of a system, although at varying intensities.

Technical Performance Measurement Vital

The Army is particularly interested in technical performance measurement. Three essential components are: (1) identification of measurable performance parameters; (2) tracking and reporting of status; and (3) problem analysis and forecasting. Each has its own degree of difficulty and risk for the contractor. The challenge that each presents is the problem of identifying the component which is critical to system performance and the problem of allocating the measurable parameter to that component that will assure attainment of the system goal. A test program that will be revealing and reflective of system performance should be devised and written into the plans. Last but not least, alternatives and contingency plans depending upon the results of the test program should exist.

Reporting Burden to be Minimal

While the Army urges documentation of SEP to be followed it does not want to add to the contractor's already heavy reporting burden. It does not wish to inhibit or delay the timely, conscientious, and fruitful application of the system engineering discipline by adding excessive, routine, by-the-number documentation requirements. Rather, the creative, helpful, and productive aspects of documentation will be emphasized. A mandatory feature of SEP is that it provide traceability. The mechanics for accomplishing the accounting aspects of traceability must be provided in the system documentation.

Figure 8 shows the multiple application of data contained in system engineering documentation. Each of the activities needs the system engineering elements of information. If they were not available from a single source, they would have to be developed. With system engineering controlling the establishment of performance requirements and acting as the controlling mechanism to the development process, all departments have a single source of information and can work to the common objectives of control of costs; improvement of systems, and better compliance with schedules.

SYSTEM ENGINEERING DATA ELEMENTS	DESIGN	DEVELOPMENT	PRODUCTION	PRODUCT ASSURANCE	FACILITIES CONSTR	TEST & EVALUATION	TRAINING	RELIABILITY	DEPLOYMENT	OPERATIONAL	DEPOT REBUILD	MAINTENANCE (MEADS)	LOGISTICS SUPPORT	PRODUCT IMPROVEMENT
OPERATIONAL FUNCTIONS/REQMTS	X	X		X	X	X		X		X				X
MAINT FUNCTIONS/REQMTS		X		X	X	X	X	X	X			X	X	X
RELIABILITY/MAINT/REQMTS	X	X		X	X			X	X			X	X	X
EQUIPMENT DESIGN CRITERIA	X	X	X	X	X	X	X	X		X	X	X		X
EQUIPMENT DESIGN SOLUTIONS	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FACILITIES REQUIREMENTS	X	X		X		X	X		X			X	X	X
FUNCTIONAL PERFORMANCE TIMES		X			X	X	X		X	X		X		X
TASK DESCRIPTION/SKILL REQMTS		X		X	X	X	X	X				X		X
OPERATING PROCEDURES		X		X	X	X	X	X	X	X				X

(Column group heading: PLANS AND ACTIVITIES)

Figure 8. Multiple application of SE data elements

BARRIERS TO RATIONALITY IN SYSTEMS MANAGEMENT

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Introduction

The quality of rationality is regarded as a necessary if not sufficient condition to the practices of systems management. The obstacles to the effective achievement of rationality are numerous; they range from the most obvious to the very subtle. The purpose of this section is to explore and characterize a few of the more persistent obstacles. Examples will be offered which will demonstrate, it is believed, that it would be naive to expect achievement of any near-optimal levels of systems management without facing up to, and overcoming, these constraints.

While the illustrative themes for this section are drawn primarily from observations of aerospace activities, it will be evident that the basic forces at play permeate society. These forces seem to accompany the human condition wherever numbers gather for purposeful group effort, where information exchanges occur involving uncertainties concerning future events which affect the participants, and especially where the contributors to the process feel themselves in some sense to be competing.

A conclusion drawn from a review of the illustrations suggests that the common characteristics of these barriers to rationality are that they seriously constrain, they are not very subtle, and they are not easily overcome.

Definitions

For purposes of establishing a common language base, I will use the term "systems management" in the formal sense as it is defined in Air Force Manual 375-1, and as it is condensed on the announcements to this meeting; viz., the process of planning, organizing, coordinating, controlling, and directing — organizations to accomplish — objectives.

I will define rationality in the manner presented at last year's ASQC Technical Conference by Professor Melvin W. Lifson:

Rationality, which means making those decisions which are most likely to result in achievement of objectives, implies the following:

1. The decision process and its elements ought to be identified explicitly so that bases for decisions can be reviewed and discussed.

2. The elements of the decision process ought to be quantified so that errors in logic can be minimized through the application of the laws of mathematics.

3. The descriptions of the real world (i.e., the models) ought to be realistic.

4. The models and their manipulation must be manageable with the economic and technological resources available [11].

The rational approach in this view is one that strives to be explicit, leans toward numerical rigor where possible, is true to the real world, and is feasible when considered against the background of probable resources available.

Assumptions and Limitations

One element of rationality concerns the modeling of the real world. The nature of the real world is controversial, as is the nature of man. I will assume that there is purpose in human life and value in activity that fosters a continuation of the human experiment. Thus, it is rational to devise systems of organization involving man and machine relationships which permit the evolution of latent human characteristics and permit him to actualize his potential, and irrational to deny this or tend to diminish the possibility of this occurring.

It should be clear that the definitional guides to rationality presented do not relieve us of the need to indulge in subjective assessments. This follows since there are many areas where adequate criteria to objective judgment of rationality may be lacking. However, the application to a good many situations is clear-cut and practical and we are at least very far ahead of a situation where the degree of rationality may be said to be "in the eye of the beholder!"

The difficulty in applying rigor increases as we move from the physical to the social and political sciences. It is a commonplace observation to note that systems management and the techniques it rests upon have had their share of fad and fancy; so, too, have the physical sciences. It may be useful to comment at this point on the difference between the more enduring truths and today's popular version of it, and the semantics applied to it.

Paradigms and Conventional Wisdom

Scientific truth develops into an authoritative consensus through a process described by Kuhn [12] as movement from one paradigm to another. Without a frame of reference of paradigm to view facts, the same phenomena are viewed and interpreted differently by various investigators and slow if not chaotic progress results. After a paradigm in science triumphs, natural science proceeds smoothly and the common orientation enables rapid progress in filling in on new knowledges and in refining the old.

Conventional wisdom is the term used by Gailbraith [13] to refer to the short-term social and economic consensus of ideas which achieve acceptability. Acceptable ideas are viewed as having great stability and are therefore much used as yardsticks for predictability.

As an illustration of economic conventional wisdom and the sudden dawning of an opposition, consider the following excerpts from the Wall Street Journal:

1. 'From the local chamber of commerce to the canyon of Wall Street, a deep faith in economic growth is a fundamental part of the American tradition. As it nourishes each American's hope for a better life, its value becomes a sacred assumption. To question it is to threaten the American dream itself."

2. "Now there is unquestionably some truth to the idea, and as it has dawned on assorted conservationists, ecologists and others, it has produced a theory: Since the U.S.' supply of natural resources is finite, open ended growth of an economy with an increasingly voracious appetite for them is intolerable; if our land is to continue to support life, economic growth must be halted or even reversed; Americans must somehow create a 'no-growth' economy [14]."

The world of industrial technology and the arena of systems management are overlaid with engineering and scientific paradigms and much conventional wisdom. Thus, there is a considerable conservative force which acts to stabilize assessments of rationality by reference to a large body of standard past practices, beliefs, and approaches. By referring to past usage, we can approach arguments concerning the validity of quantifying decision elements, or the degree of realism in a math model, or the manageability of the resources needed to accomplish an innovation in a new technology, with at least some confidence. The more our confidence in engineering estimates is raised, the more documentation of past performance can be brought in, which show that the same or analagous routes to the ones proposed have led to project success.

But, throughout, we will have to consider that in the legacy we receive from the past there is a residue that persists, not because of a demonstrated utility in support of the prevailing scientific or engineering verities but because of the workings of "conventional wisdom."

Barriers to Rationality in Systems Management

The Management of Hidden Assumptions. Decision-making involves the balancing of a multitude of explicit and implicit factors. Inputs may come from the disciplines of physics and engineering as well as aesthetics and politics. Whatever the sources and whatever the constraints, the decision-maker must develop clean lines of responsibility to cope with the tradeoffs, or rationality will suffer. His strategy for handling hidden assumptions is crucial.

Honest forecasting by dedicated skilled analysts may be desired in a given project management situation. Sometimes, what is really desired is an analytical confirmation of a preconceived position taken by the project manager. This may have come about due to "seat of the pants" intuition or from consideration of some heavily weighted political factors about which the project manager alone is knowledgeable.

A fairly common problem is the one in which the project management is aware that the customer has invested special meanings of "feasibility" or "nonfeasibility" to particular ranges of predictive performance index values. Following an engineering analysis whose results contain pessimistic performance prediction numbers, the project manager can (a) bury the report, (b) ask that it be redone, showing favorable numerics, (c) request that the sensitivity of results to uncertainties in the data and model be thoroughly reviewed, and (d) accept it as given and add this to other inputs. Either (c) or (d) constitutes the rational response which is readily understandable and assimilatable by the engineering staff. The choice of (a) or (b) constitutes a contamination of the information process and a stultification of the systems management approach.

There are, of course, sound reasons for the project manager to process inputs and to exercise his unique judgment in establishing the project position. There is no particular contest here, and no great subtlety. It is perhaps one of the most common and best understood facts of project life.

Engineering analysts operating in this context are generally sophisticated enough to realize that the ultimate exposable management prediction tool is the one which fits the total needs and current strategy of the decision-maker. Any tool which yields answers that are not compatible with the manager's inner frame of reference is bound to be unacceptable. The analyst may dwell on the job-security implications of behavior that does not fill an obvious need. The self-serving analyses that result are, of course, directly inspired by ambiguous management behavior. It is curious, but not surprising, as to how many managers will opt for organizational ambiguity and who are content to achieve irrationality by default rather than to be seen in any direct intervention and contamination of the input process.

There is a strong pragmatic justification for the rejection of rationality in a number of instances. These come from those managers who have experienced successes in systems management generally functioning with close-knit dedicated groups, where cost-effectiveness has not been a significant criteria of worth. Here, there is a highly developed level of conventional wisdom that sets itself above the claims of the prevailing technical paradigm. The assertion is made that the complexities of the enterprise are too much for thorough analyses, and the time from engineering concept to hardware delivery is usually too short with the resources available to seriously consider integrated rational planning as a valid approach. To suggest this aloud would cause controversy; therefore, ambiguity is chosen as the way of compromise. Whatever the basis for the adoption of these tactics, the net result is the sacrifice of rationality.

<u>The Blurring of the Education-Sales Interface.</u> There is undoubtedly a definite need to develop clearer lines of demarcation between the education and the selling roles of the different personnel in the industrial enterprise. Certainly the functions manned by marketing personnel where they exist are commonly understood to be the exercise of the prime machinery for the selling activity. Also, some managers in the past understood that they would be educated with the help of their engineering and other project staff, after which they could be counted on to sell necessary points of view and ideas to the customer or to higher management. Now, the tolerance for the use of engineering and assorted other personnel as salesmen to permeate the organization appears to have reached unusual levels of acceptability. Consequently, the burden on rationality and system management is enormous.

There are undoubtedly many reasons as well as extenuating conditions which help to explain the circumstance described. A significant factor is the rapidity of changing technologies, which has created demands for narrower and narrower fields of specialization. This in turn has created some obsolescence of engineering talent, including sales engineers. The difficulty of developing an adequately trained sales staff in such a competitive labor market is clear.

For this reason, as well as the mismanagement of the hidden assumptions mentioned earlier, many systems managers have found their support activities heavily invested with a salesmanship role quite distinctive in characteristics from the education role they had in the past. This change in role structure may have gone deep into the organization, with each level sensitive to the political needs of the next higher level. Naturally, in this process, rationality in decision-making will suffer.

Curiously, there are many managers and engineers in aerospace who have been so accustomed to what has become a way of industrial life, they fail to discern any significant and practical differences in the change that has occurred. To exhibit the crucial distinctions that education and selling have for the process of rationality, I have prepared a matrix which helps define the framework in which each process is carried out. This is shown in Table 1.

TABLE 1. CONTRASTS BETWEEN EDUCATION AND SELLING

	Education	Selling
Basic Objectives	Affect a change in the individual and possibly between the individual and society, based on conveying a clear conception of reality or developing or enhancing an ability to achieve the same. An attempt to realize a fuller utilization of human potential.	Instill a desire or want in the individual which will make him receptive to a particular course of action. An attempt to gain acceptance of the product.

TABLE 1. (Continued)

	Education	Selling
Protagonists	The teacher believes what he conveys; he has loyalty to the integrity of the education process — which may conflict at times with society or institutional loyalties.	The salesman may believe what he conveys. He displays loyalty to the product or to the institutional sponsor.
Basic Process	Primarily an ingenuous appeal to conscious, aesthetic, rational sensitivities, and sensibilities of the audience.	Primarily an ingenious appeal to conscious and/or subconscious factors.
Constraints	Deceit and illogical approaches are not admissible. Educators cannot be salesmen; the only sales product possible in education is the education process and its enhancement.	Deceit and illogic are permissible. Dependent upon value constraints, extra legal action may be condoned. Salesmen may be educators. They may elect to sell only what they believe in and use only the techniques of the educator. However, they may be relatively deficient as salesmen (if not totally ineffective) since they lack total loyalty to the product and forego possible effective approaches open to other salesmen.
Values	Educator chooses methods which are harmonious with end goals.	Salesman may use any legal means which may prove effective in achieving goals.

TABLE 1. (Concluded)

	Education	Selling
Motivation	Educator interacts to affect pupil maturation through awareness changes.	Salesman attempts to develop behavioral responses independent of any necessity to obtain maturation or secure self-awareness.
Options	Educator considers alternate choices and suspended judgments and probabilistic solutions.	Single product oriented, with deterministic solutions preferred by the salesman.

It should be clear from Table 1 that the need of systems managements is to cultivate the educational aspects in all interpersonal relationships within the enterprise, if the rationality objectives are to be preserved. It should also be advanced and acknowledged that this is a necessary if not sufficient criteria for the establishment of management excellence. The basic obligation of management is to establish and control the tolerable levels of salesmanship. Unless such basic policy is apparent, the levels below will choose to interpret their roles in the usual self-serving manner and ambiguous role playing will permeate the organization.

Concepts of Leadership Styles. Conventional wisdom has evolved several models of the professional manager and his management style which are not necessarily compatible with rationality. To illustrate grossly the types of industrial leadership, Thompson [15] proposed the matrix given in Table 2.

Clearly, rationality requires two-way communication, a trained and competent organization, free-flow of information, and the absence of coercion. This would suggest that only some types of leadership are compatible with the concept. In addition, if we observe our add-on assumption that rational uses for human beings are only those man-machine relationships which permit the growth of inherent human potential, we do not have the freedom to choose among all these options.

TABLE 2. TYPES OF LEADERSHIP

Feature	Autocratic	Bureaucratic	Diplomatic	Democratic
Motivation	Power	Personal prestige	Program advancement	Personnel and program advancement
Objective	Immediate results	Impregnable system	Individual development	Group development
Authority source	Self	Rules & regulations	Higher management	Group
Communications	One Way	Avoided	$1\frac{1}{2}$ Way	Two Way
Methods	Orders	Procedures	Persuasion	Information
Morale	Apathetic	Negative	Competitive	Cooperative
Results	Extreme	Mediocre	Fair	Superior
Reason for choice	Uninformed organization	Unimportance of Individual	Untrained organization	Trained and competent organization

Yet, in many aerospace companies the management training advice takes the form: "Expose yourself to many leadership styles and choose the one that enables you to achieve maximum effectiveness." The consideration of most worth in these discussions, I have found, is short-term effectiveness and short-term success. Under this view, the treatment of human resources is essentially the same as the other material resources available to management, and tradeoffs are made to effect an optimum solution to project problems with no serious effort to introduce human values as a project constraint.

The efforts to motivate the individual under this regime are simple. Provide attractive financial lures that require that he submerge his short-, medium-, and long-range goals and objectives as a professional, and enter into an excitation state which is harmonious with, even identical to, the outlook of the current autocratic leadership. I would characterize this as the use and abuse school of management.

The character of the abuse sustained by the individual may be contestable. If you believe that the individual adult has only himself to blame if he is manipulated, however subtly, by the social and other forces about him, you may not consider the organizational forces of sufficient significance to warrant active concern. Some would insist that as long as there is a free play of manipulative forces in the open market place, some will cancel others and the net effect in the long run could be beneficial. It remains beneficial just so long as the rugged individualist maintains his freedom as a prey to the competitive manipulative forces and is not forced to succumb to any single oppressive force. People are always being used, and under this view, the only undesirable thing is the abuse caused by a user monopoly.

It should be clear, however, that a person making his way through this fun-and-games manipulative market is most assuredly a cautious cynic who is spending as much time understanding the politics of running fast enough to maintain his status and prestige in the political sphere as he is in guarding against obsolescence in the educational sphere. He is fast learning to sell himself, and, here, the best requisite is to pay lip service to rationality, and to watch for and defer to the centers of the real organizational power.

As in many systems engineering optimization problems, the consideration of most worth is the definition of the system being considered. Industry and Government that foster the conditions which call for the use and abuse technique can trade for these successes in numerous ways. There is, for example, huge turnover of personnel wherever personal fulfillment is not achieved. (Outgoing personnel testify in termination interviews that the corporation paid no attention to the matters that mattered most to the individual.) Again, rewards under this system oftentimes go to the less deserving; or at least it may be said that the system does not have adequate criteria to sense the contributors providing the more lasting inputs. There is a steady loss to industry of its most creative personnel; there is loss to the project of innovative schemes. Finally, there is waste and duplication and deceit tolerated by a matrix of power struggles and cliques fostered by the system which is somewhat cynical in its total recognition that manipulation is the name of the game.

Management of corporate enterprises are only grossly constrained to seek goals using methods that are harmonious with the government framework in which they operate. In democratic governments having something akin to a Judeo-Christian heritage, it would presumably be unthinkable that the dignity and worth of each individual would not appear in some form as a basic guide behind the generation of policy and procedures governing much of the day-to-day work, and manager-employee relations. While in the plane of the theoretical and abstract, this may be universally acknowledged, and in the gross form followed (e.g., no corporations within the U.S. employ slave labor), it does not appear to be a significant detail factor in the frames of reference employed by the dynamic executives of the use and abuse school.

In the alternate view, the exercise of organizational pressures constitute an abuse wherever it is applied without consideration of the individual's aspirations and potentials. It is abuse, in this view, since it tends to substitute a value system which places undue stress on acquisitiveness, power-seeking, salesmanship, and places these qualities along with corporate conformity on a higher plane than creativity, innovation, diversity of expression, cooperativeness, reason, and education. This is abuse because the recipients of pressure lack the flexibility, the strength, or the wisdom to resist.

Of course, one can observe these extremes operating in and outside the aerospace industry. However, it is demonstrable, I believe, that inside of this world the use and abuse approach accounts for the great preponderance of successful projects. This is not saying anything more than the obvious. More projects terminate successfully using this approach because more starts are made with this kind of management leadership. The periodic flagrant dislocations involving personnel are equally evident, although the total costs of these to society are rarely tallied.

It should not be surprising that in the spectrum of industrial leadership, a substantial category believe that the techniques that they observed as effective in their businesses are for that reason preferable everywhere. As increasing numbers of the business leadership pay lip service to the values of the social heritage, these values erode. The forces that bind government, industry, schools, organized religion, and the family unit into an integrated cultural whole begin to change. The change is a response to the short-range effectiveness school.

Management Ethics. By far the greatest threat to rationality in systems management comes from that part of the conventional wisdom that holds that the business world's standards of value and managerial ethics are and should be totally different from the other sectors of society. One of the clearest expressions of this point of view has been given by Carr [16], who was Assistant to the Chairman of the War Production Board during World War II, a special consultant to President Truman, and has since been a management consultant and writer:

> We live in what is probably the most competitive of the world's civilized societies. Our customs encourage a high degree of agression in the individual's striving for success. Business is our main area of competition, and it has been ritualized into a game of strategy. The basic rules of the game have been set by the government which attempts to detect and punish business frauds. But as long as a company does not transgress the rules of the game set by law, it has the legal right to shape its strategy without reference to anything but its profits. If it takes a long-term view of its profits, it will preserve amicable relations, so far as possible, with those with whom it deals. A wise businessman will not seek advantage to the point where he generates dangerous hostility among employees, competitors, customers, government, or the public at large. But decisions in this area are, in the final test, decisions of strategy, not of ethics.

Mr. Carr's article expands on the thesis that business operates by game strategy and, short of "outright cheating" or violating the law, you optimize your chances of winning independence of anyone's notions of morality. He quotes A. Taylor, British Statesman: "Falsehood ceases to be falsehood when it is understood on all sides that the truth is not expected to be spoken." Mr. Carr cites such things as deceptive packaging practices investigated by Senator Philip A. Hart of Michigan, the automakers' neglect of safety as charged by Ralph Nader in his book "Unsafe At Any Speed," the overcharging by utility companies exposed as evasions of law by Lee Metcalf and Vic Reunemer, a documented charge of unethical practices levied by D. P. Moynihan against insurance companies. He references the actions of a key manufacturer who provided master keys to mail-order customers, including thieves, and a mouth-wash manufacturer who knowingly sold a produce injurious to health. The proper response of the businessman to all of these, says Carr [17], is simply this: "If the law governing their businesses change or if public opinion becomes clamorous, they will make the necessary adjustments. But morally in their view they have done nothing wrong."

There can be no doubt that systems management cannot function in any simple rational manner when dealing with such a game of strategy. If Carr's portrayal of this world is taken as accurate, the systems manager coping with such businesses has to resort to appropriate defensive tactics to assure the necessary free flow of information required for valid decision-making.

This may take such forms as considerably more extensive assurance control and documentation than would otherwise be required for a given complexity of task.

Systems Management will be concerned with effectiveness criteria that equates with the real needs of citizens, especially in the civil systems sector. Optimization approaches will have to consider the public, the government, and the businesses as an interwoven, organic whole. This will be impossible to achieve under business-game approaches that do not have a value system compatible with the best aspirations of society.

Finally, we should consider the implications of Carr's thesis on a global evolutionary scale. If some men have lost faith in a single, god-derived, and religion-propogated moral base (which is applicable alike to the office and the home), perhaps they can entertain the replacement worth of more humanistic philosophies such as those advanced by Huxley [18] and de Chardin [19]. One pragmatic explanation of man's development of a conscience and a sense of morality is that it is genetically propagated, having come about through a demonstrated superiority of those species on the evolutionary ladder which held a higher sense of value for social cooperatives and group effort for mutual good [20]. If this is true, the "ritual" business game strategy cultivated consciously and assiduously may be viewed as ultimately leading to a retrogressive evolutionary type (RET). We may then classify the breed of the RET culture as a group of humanoids who have chosen to turn their backs on the possibilities for fulfillment in the evolution of humanity.

To a reader who wrote; "A man cannot separate the ethics of his business life from the ethics of his home," Carr responded: "Over the long run, that is probably true. What happens is that, in too many instances, the ethical outlook of business comes to dominate in the home as well. Perhaps that accounts in part for the notorious instability of the middle-class home in our society, and the increasing revolt of the young against the corporate establishment [21]."

It should be added, finally, that Carr feels that "sound long range business strategy and ethical considerations are usually served by the same policy [22]."

If Carr's thesis is examined closely, it conveys the notion that the liklihood is great that, far from reaching the strategically desirable ethical heights, the "higher" morality of society will be debased by the tactical business approach. Not only does the businessman bring his morality to the home, as Carr suggests, but he and his family are members of the public and influence the educational process disproportionately as private citizens and as spokesmen for society's leadership. Businessmen wield exceptional power over legislation by virtue of lobbies and support to political candidates. In addition, by virtue of knowledge and/or influence, they are often chosen for the governmental regulatory and other watchdog agencies. If this is true, how can Carr be so complacent about business adjustments to a higher morality brought about through a clamorous public and a concerned government?

The Optimism of Practitioners of Systems Analyses. Successes during World War II with systems analyses and the techniques of Operations Research have led enthusiastic supporters to overstate the power of its applicability in valid support of systems management, especially in the civil systems area.

Joseph H. Engel, former President of the Operations Research Society of America, has said:

> "We are very good at hardware and tactical problems and starting well-defined research and development programs. We're lousy at strategic and philosophical problems — We need to put all our 'people-oriented' people to work on these problems. I see a very long and difficult road ahead — Systems Analysis, based solidly on observation and careful reasoning, is the only method powerful enough to accomplish valid analysis of the major social problems of the world today [23]."

Following this "upbeat" (his word) message, Engel proceeded to detail a number of problem areas which suggest that there is indeed a long, long road ahead. He mentioned the need for the system analyst: To display his limitations honestly; to characterize explicitly the values he applies to the system, and if these are debatable or changing with time, to explore the effects of varying assumptions about values; to avoid over-simplification especially on measures of effectiveness which cover performance and which may be incommensurate; and to report inconclusiveness and statistical uncertainties [24]. Many of these points he reiterated as a member of a panel on military operations research at the Miami meeting of ORSA in November 1969. There was fairly good agreement by the distinguished panel on "Whither Military Operations Research?" that if Operations Research (OR) continued as it has in the past 5 to 10 years, it will wither and die and that all evidence pointed to a steady deterioration in the meeting of the promises of a decade ago. Berger, on the panel, noted[1]:

[1]Notes by Howard M. Berger, taken at the 35th National Meeting, Operations Research Society of America, Miami, Florida, November 1969.

1. Proposal writing supported by OR specialists for institutions is a form of business prostitution.

2. Problem-oriented practitioners of OR are to be preferred over technique-oriented ones. "If you have done your thesis in linear programming, all the world looks like linear programming; a Ph.D. in OR is, by and large, a person with a technique in search of a problem to apply it to."

3. The complex computer model is to be as distrusted as the simple-minded one; it produces no better answers. About the best one can say is that it is at least as good as a simple one.

These and other specialists were quite frank in detailing the failures or meagerness of successes in the use of OR techniques not only in the military area, but also in law enforcement and crime prevention, in the "developing" countries, and in civil systems areas. There was obvious vitality and eagerness in the fraternity to get on with the business of applying the proper corrective measures, but there was also recognition that increasing humility was called for, along with the passage of some time for obtaining missing data and wisdom concerning measures of effectiveness involving value systems.

The effect of overstatement of a discipline produces a natural reaction. I believe the issuance and reaction to "Special Study Group" reports such as the Reference 25 show the thin line of demarcation of some serious system analyses efforts and a hoax. It seems that the appearance of profundity and the substance may be hard for the layman to detect, and the decision-maker in systems management may be equally justified in maintaining his keenest discrimination faculties at all times.

The Denver Research Institute report on systems analysis reviews the 1965 State of California effort under four contracts with aerospace companies and finds the studies valuable and interesting and the techniques definitely of future value in some civil system areas if obstacles are overcome. The summary included the following remarks:

> The ultimate discipline of government is the effective performance of a public responsibility. The ultimate discipline of a corporation is the making of a profit. Each must serve the other's discipline if the partnership between them in pursuing public programs is to work. The dangers at the moment are that government will not do enough to serve industry's discipline while seeking to involve it in new areas; that industry will be forced to cut off the long-range potentials in applying systems techniques because of a need for short-term gains. If these dangers are realized, the public will lose an important opportunity to

discover what the thoughtful use of systems approaches can mean in creating a new environment for the human spirit [26].

The literature critiquing the systems analyses approaches, like some of those quoted above, contains similar statements of existing obstacles to the immediate utilization of the disciplines coupled with expressions of faith in the ultimate beneficial power of the techniques [27].

Summary and Conclusions

Systems management implies rationality. It has been asserted that some of the barriers to rationality which seriously constrain systems management come about through:

1. Mismanagement of hidden assumptions.

2. Blurring the education-selling interface.

3. The use of incompatible models of leadership styles.

4. The use of the conventional wisdom that business ethics should be different from society's ethics.

5. Overly optimistic attitudes concerning the present validity of systems analyses.

The scientific method as a laboratory discipline has developed techniques to overcome investigators' biases wherever these could be explicitly identified. The discipline of systems management must similarly scrutinize itself and clean house, if society is to realize its promises.

SUBTLETIES OF SATURN SYSTEM ENGINEERING

Malcolm A. Cutchins, Associate Professor of Aerospace Engineering, Auburn University, Auburn, Alabama[2]

Introduction

Many articles have been written concerning the recent successful moon landing. Few of the authors, however, have enjoyed the unique experience of actually discussing, face to face, some of the reasons for the success with several dozen of the key technical and managerial people closely involved in actual design, engineering, and management of the Saturn itself. This section is an attempt on the part of the author to convey some of the results of these interviews which were conducted at Marshall Space Flight Center (MSFC) in Huntsville, Alabama, during the early part of 1970. It is not the intent to present the well-documented tools of system engineering [28] and the tremendous impact they had on the development of Saturn technology. Instead, emphasis will be upon those things which these key Saturn people have identified as being pointedly influential in the successful application of the systems approach. These ideas should prove useful in applications of the approach in almost any field of endeavor.

To have a frame of reference, system engineering is defined as:

> The process of applying science and technology to the study and planning of a system so that the relationships of various parts of the system and the utilization of various subsystems are fully established before designs are committed [29].

Interviews revealed differences in semantics, but no major disagreements with this definition were uncovered. For those who perhaps think that this is a very new way of thinking, the quotations below indicate similar ideas promoted many years ago:

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[2]Dr. Cutchins is presently at Marshall Space Flight Center in Huntsville, Alabama, on a 9-month study grant on systems engineering in the Technology Utilization Office.

"If we could first know where we are, and whither we are tending, we could then better judge what to do, and how to do it."

Abraham Lincoln 1864

"A sensible man watches for problems ahead and prepares to meet them; the simpleton never looks, and suffers the consequences."

King Solomon 700 B.C.

Figure 9, from an excellent General Electric System Management Course [30], is a summary of NASA documentation related to phased project planning. Note the absence of documentation for introduction, philosophy, and policies for systems management and systems engineering management. This gap of documentation does not exist in similar summaries for the Army, Air Force, Navy, and the Department of Defense. It should be a most convincing lesson to see that engineering of the Saturn could be done without formal documentation thoroughly covering these two areas. Certainly then, one cannot count on such documentation to "get the system engineering job done" on future projects. This is not to say the documents are not needed, or that they would not help smooth the process. But, as an example, Assistant Secretary of the Navy Robert A. Frosch in a recent article [31] described some of the "bad system engineering" which can result when paperwork is an end in itself. It is conceded that much paperwork is needed and useful, but this article will not be concerned with that subject except in mentioning this warning.

Keys to Success

With a very broad concept of system engineering, Figure 10 shows areas which seem to have played major roles in the system engineering of Saturn at MSFC and at their contractors. These are not meant to depict any particular organizations. It is significant that only recently has the area shown dotted been organized as a separate group at the Center itself. For this reason, no interrelationships involving it are depicted. Additionally, the interrelationships involving management and advanced studies are omitted from the figure for clarity. Only those characteristics or functions (or perhaps what might be called identifiable influences) which most meaningfully contributed to the successful engineering of Saturn are covered in this section. While primary emphasis is on MSFC, these influences permeated the entire MSFC-contractor team effort.

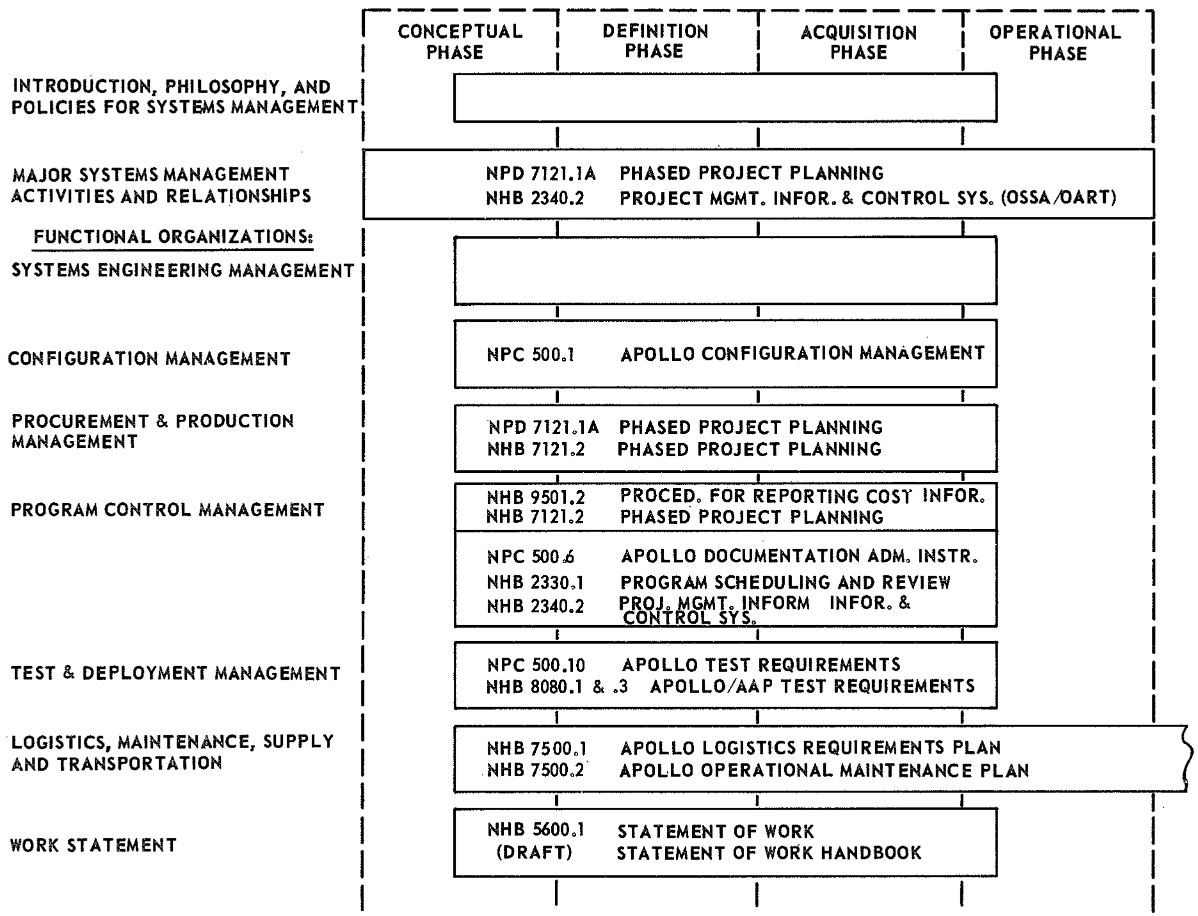


Figure 9. NASA manuals for phased project planning (and their relationship to the life cycle) [30]

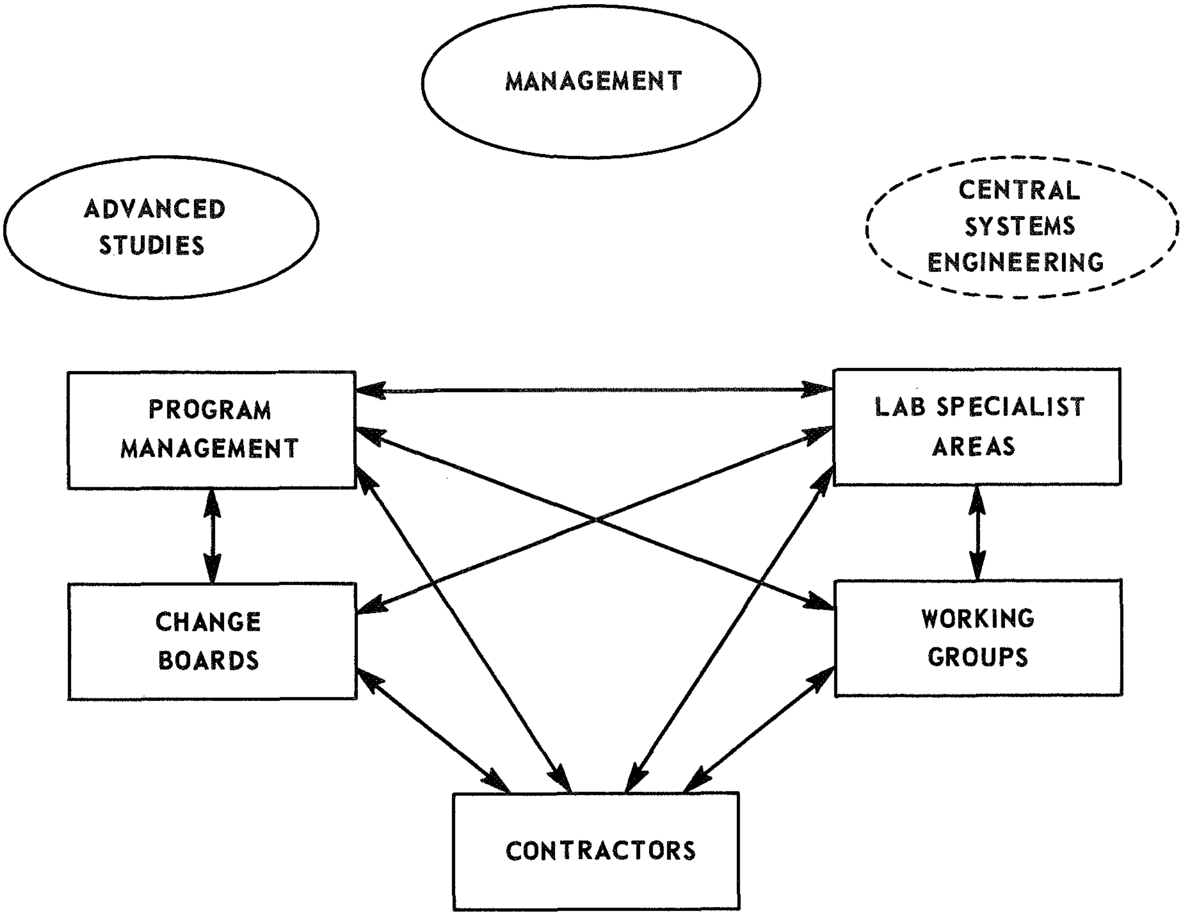


Figure 10. Areas of MSFC systems approach applications

The keys to success of Saturn systems engineering are as follows:

1. Goal and time frame.

2. Technical specialists' strength.
   a. Leadership and experience.
   b. Inherent motivation of the space program.
   c. Automatic responsiblity.
   d. All success planning.
   e. Flexibility of organization.
   f. Visibility.
   g. Communication and openness.

Without question, the most important key was that of having an explicitly defined goal with a rather definite time frame of accomplishment. If this seems trite, one need not look far to see how much this is lacking in almost all of the approaches taken to solve the problems which face us today. This key, more than anything else except competent people, makes tradeoff decisions effective and more likely to be correct. It must be more explicit in statement and time frame than the often heard, "we must stop pollution!" or, "we must stop crime!" This goal and time frame must be projected in such a way that one man or group of men feel the responsibility for accomplishing the goal and are given the resources with which to do it. It must be stated in such a way that what might be called a "technical optimum solution" can be ascertained. Quantification must precede solution.

Secondly, technical specialist strength was emphasized by each man interviewed. This strength or capability was a result of competence gained not only through formal education but, more importantly, through years of continuing education and the tutoring of many years of experience. These specialists knew what they needed and insisted that stage managers and contractors follow their recommendations. There was no question that technical truth was king. While many may criticize overspecialization, a real danger exists for too many to over generalize at the expense of technical depth. If there was one point in these interviews that fell in the category of being within each individual's grasp, it was this point of developing depth in one's chosen field of study. Machol [28] makes a similar plea.

The remaining points listed above are not placed in any particular order. All played an extremely important role.

Leadership and Experience. All organizations hope to achieve the correct balance of leadership and experience, and even if such a state is ultimately reached, flexibility must provide for adaptability to change. So what was unique with Marshall's success in this particular area? Technical specialist strength has already been mentioned, but in addition there was systems-oriented leadership and team experience. Many are familiar with the role of some of these leaders, their dynamic personalities and their own technical capability. They had perceptiveness in questioning, remarkable judgment in establishing basic constraints, and the ability to pursue a problem all the way down to the nuts and bolts when needed.

Team experience contributed in many ways. The inhouse capability developed on Redstone-Jupiter Programs at the former Army Ballistic Missile Agency, the Penemunde experience, and varied contractor experience had a very definite impact on Saturn. Incidently, on what broad, complex problem that we face today has there been a dedicated core group of the size and capability of the "von Braun group" working together for a period in excess of 30 years? Of primary importance was the team effort of MSFC and contractor laboratory specialists working together in establishing a professional position on technical decisions that came to receive the highest esteem. Responsibility throughout gravitated toward the man with capability. Age, rank, and position had much less to do with it.

The Inherent Motivation of the Space Program. This motivation may not be significant except to serve as a warning that such inherent motivation may be missing from attacks on many of the socioeconomic problems that we must solve. How can a person be motivated to do just as good a job on an auto part, for instance, as he would on a Saturn part? This motivation is no small influence; however, it may be difficult to measure. In addition, the motivation of manned space flight was extremely significant. Some have even conjectured, "maybe we could not have made it with an unmanned flight." The formal Manned Flight Awareness Program contributed greatly to both individual and group motivation. By emphasizing the importance of the crew, a number of important system constraints predominated. Among them were: (1) failures, should they occur, had to be controlled failures, and (2) system safety considerations had the highest priorities and were introduced in the earliest phases possible.

Automatic Responsibility. The laboratory directors at MSFC assumed direct responsibility for the discipline areas of their labs on the vehicle. There was no wait for work orders, and no wait for program management. A lot of problems were uncovered and even if instances occurred where unneeded specifications were imposed, or some over-reaction took place, a confidence developed that nothing would, as some say, "fall through the cracks."

All Success Planning. The "all up" concept promoted by Dr. George Mueller of NASA Headquarters (i.e., the parallel development of all stages of the vehicle simultaneously) was certainly an important factor. The "goldfish bowl" of national television, the practice launches, extensive testing, and extensive simulations were just a few of the contributing factors of this key. A parallel of the "goldfish bowl" on a much smaller scale exists in education. Some years ago, a study at a large university revealed the unexpected fact that students in large classes (approx. 200) were doing better than their peers in small classes (10 to 20). This was traced to preparation time on the part of the professors. They spent roughly three times the preparation before facing the large class. The conclusion is not necessarily to go to large classes, or to place everything in a "goldfish bowl" environment, but to provide in some manner the proper motivation for thorough preparedness. Saturn successes reveal such thorough preparation very spectacularly. Personal reputations and corporate images were definitely "laid on the line." Failure of one meant total disaster for all.

Flexibility of Organization. Although there were certainly many important organizational aspects which contributed to Saturn accomplishments, only two of them will be mentioned here: (1) working groups, and (2) change boards and their role in system engineering. Ironically, they were not even called system engineering at the time that they played their most important role in Saturn.

Figure 11 shows the major working groups used to solve many of the interface problems in the engineering of Saturn. While some might criticize these groups as being too informal, too unorganized, too large, unwieldy, etc., it must be remembered that at that time, not enough major planning had been done to carry out this function in a more organized manner — and the target date was ever closer. In retrospect, many feel that the working group structure was the most efficient way to have accomplished interface definitions and resolution of system problems. At least they served as useful

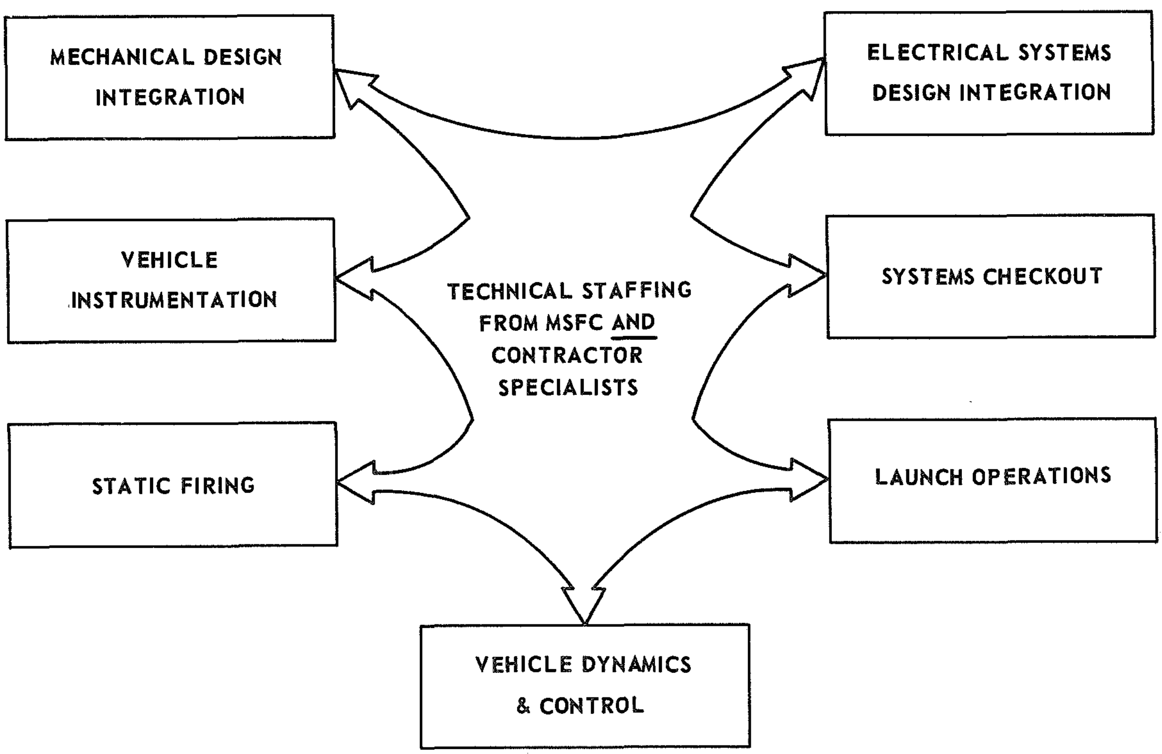
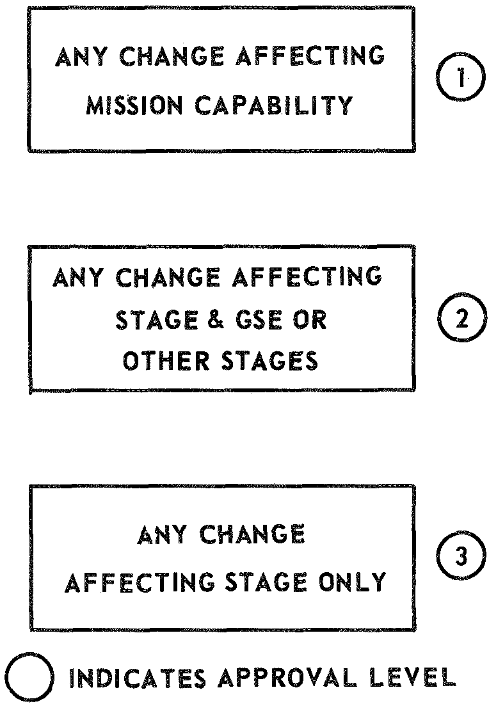


Figure 11. Saturn working groups

mechanisms for technology or information transfer between technical specialists, no simple feat to perform in many instances.

Change boards given in Table 3 performed a very important role in good systems evaluation. Changes were assessed at the three levels shown for penalties, risks, costs, disadvantages, and documentation requirements. These were not minor systems considerations in any respect. They represented collective judgments by competent technical specialists.

TABLE 3. CHANGE BOARD MECHANISM



Visibility. This area of endeavor (visibility) has too often been considered a burden or a frill. Yet it is very important in highlighting problems and is something which must be stressed if success is to be reached. One cannot eliminate the problems and therefore must identify the most critical ones. Ingenuity, flexibility, and a constant awareness of the overall goal are prime requisites for successful visibility. This can be used as the "bird dog" in flushing up "covies" of problems. It can be used in showing up trends and using trend analyses to better predict what is ahead. Progress, or lack of it, shown within a time frame, is the most important characteristic. The individual requirements for good visibility are such that it is difficult to structurize or summarize further traits. A visit to the MSFC Program Management control room which attracted national attention (or some similar endeavor) would convey much more than could be gathered from any paper. This room was often described as a meeting ground for MSFC and contractor laboratory specialists "to learn to play from the same sheet of music," in the words of Dr. Rudolph, Saturn Program Manager.

Communication and Openness. Perhaps a trite observation? Not so! Human traits tend to make communication and openness very difficult to establish and maintain. Yet to be organizational characteristics, they must be delicately balanced. And they are probably traits which never reach a status quo or enjoy a fully desired level of attainment. While there were many, many factors which influenced these characteristics in the Saturn program, two of special merit are mentioned:

1. Program reviews, which not only entailed the line elements (the project-oriented or vertical elements) of the organization, but which also included the horizontal elements of the organization like system engineering, test, quality and reliability, program management, etc. All had their "day in court," including even the individual technical specialist. Is only "lip service" often given in too many organizations to the horizontal elements?

2. Recovery plans, which were oral presentations of attack plans on the problems highlighted or uncovered by these reviews. This was found to be extremely successful.

Additionally, successful communication and openness in technical development work entail attitudes which must suppress certain usual characteristics while striving to keep more desirable characteristics dominant. Five of these are shown in Figure 12. No amount of organizational legislation can bring these about. They are best taught by that old schoolmaster, experience, and each of us probably goes through several cycles of learning and relearning their importance. Laboratory personnel were urged by top management to more deeply penetrate technical operations of contractors. An emphasis of desirable attitudes can, with proper ethics and knowledge of technical truth, lead to singleness of purpose in overall system design.

An Educational Byproduct

How can these attributes of the Saturn success best be conveyed to others? One way is an educational byproduct of NASA system engineering which seems to be successful is the NASA/ASEE Summer Faculty Fellowship Program. A total of 245 faculty members from universities throughout the United States have participated in these since 1966 at four NASA centers in connection with four universities. The programs conducted at MSFC include Project JOVE, Jupiter Orbiting Vehicular Excursion in 1967; and Project STARLAB, an orbiting Space Technology Applications and Research Laboratory in 1969 [32]. Both projects have been conducted for NASA Headquarters by Auburn University. Both have received exceptional support from MSFC and have enabled faculty members to learn many of these keys to successful implementation of systems engineering in an actual case-study learning situation.

These 11-week programs are not intended to produce fully qualified system engineers, but they provide the training experience for multidisciplinary faculty teams[3] to apply the systems approach to large complex problems. Many have said that some useful system study reports have resulted as well.

[3] Vachon, R. I.; Cox, J. E.; Cutchins, M. A.; Hamby, H. G.; and O'Brien, J. F., Jr.: A Training Exercise in System Design. Engineering Education, April 1970 (to be published).

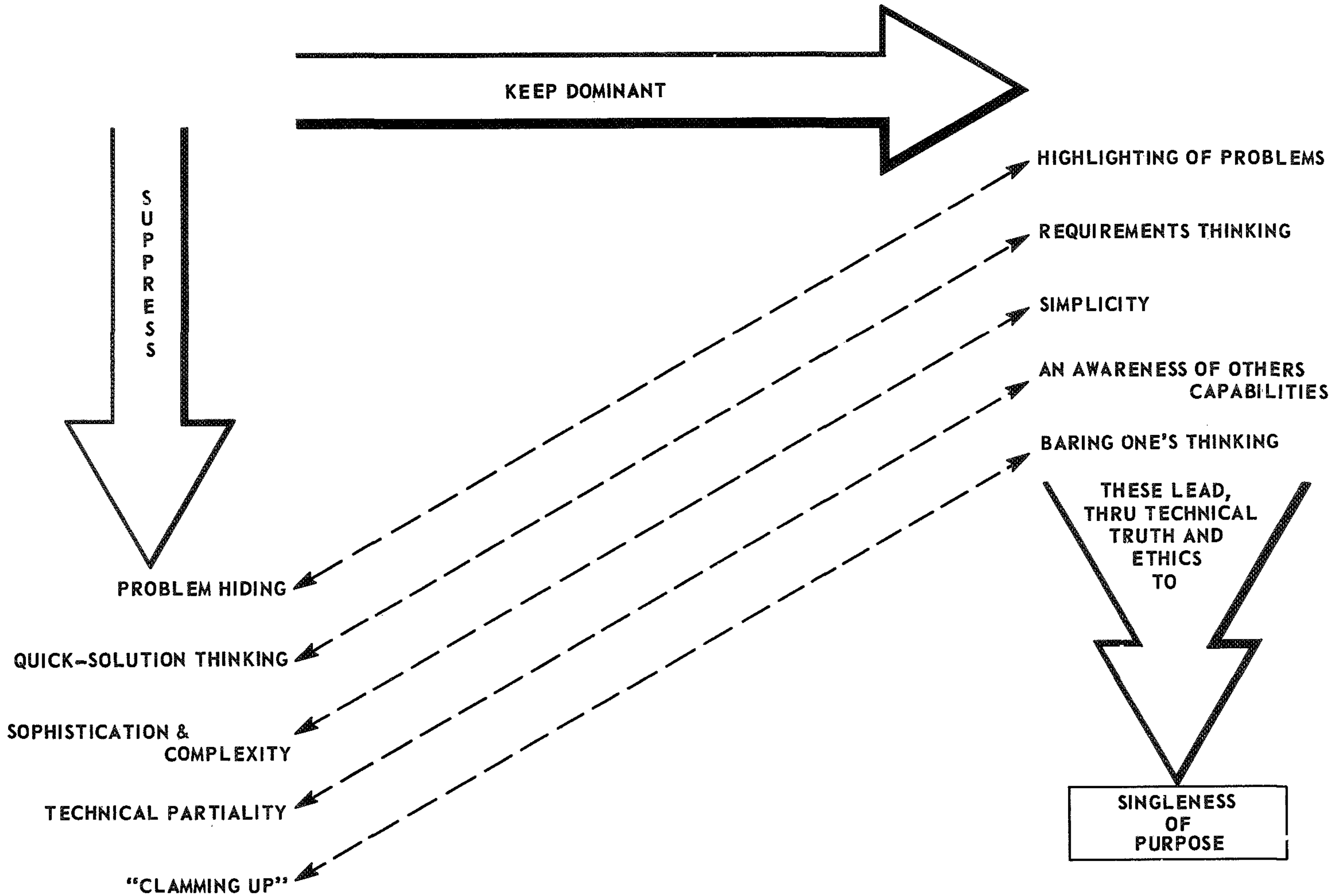


Figure 12. Characteristics of communication and openness

The very essence of systems work is in the decision-making processes. In these summer studies, it is possible to expose these professoral teams to a great variety of things which shape final decisions.

Conclusion

The story is told of the old indian who watched, over a period of time, the construction of a lighthouse near the coast. Later he observed the results and confided in a friend, "Light flash, horn blow, but fog still comes in." So it is with system engineering, the warnings, the highlighting of problems, and the visibility flags can be provided. The problems will still appear, but hopefully many ships will be saved from calamity at the interface of land and sea. As we learn from our successes and failures, it is usually not something earth-shaking that makes the difference, just subtle things, very delicately balanced. Maybe it is like a trajectory and the goal of a launch vehicle. An analogy exists between the perfect trajectory and the perfect system engineering setup. Reality and the lack of a perfect guidance and control system has us somewhat off the perfect line, but the important thing is reaching the goal. As in the Saturn guidance system, it is best not to attempt to get back on the original perfect trajectory, but to start with where one is and where one wants to be and to make the necessary adjustments to attain the desired goal. Similarly, although each contractor was responsible for a contract end item, he had to show an awareness of its influence on the overall Saturn vehicle and assume responsibility for his contribution to the attainment of the goal.

THE REVELATION OF SATURN-APOLLO

Samuel E. McCrary
Technology Utilization Office
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Marshall Space Flight Center, Alabama

When the Apollo astronauts put our lovely blue-white earth on live color TV, in full compass for all to see, I was at first fascinated by its beauty. Then I was stricken by a profound idea: "Those guys in their little space ship 'Apollo' are showing us a picture of our big space ship 'Earth.' The rules for survival on each of them are the same."

These ventures into space have revealed to us some of the goals we must achieve concerning ourselves and our ecology if we are to avoid certain extinction. That one small step by Neil Armstrong, July 20, 1969, may indeed become a giant leap for mankind toward a posterity that has no end.

As an engineer engaged in the Saturn Project for the past 8 years at Marshall Space Flight Center, Alabama, I have seen the Saturn project grow and mature from an imperfect embryonic effort into one of unprecedented perfection. It was done through assiduous trial and refinement of hardware technology and management techniques. Both of these were important, of course, but I am convinced that the most important feature of all was the attitude and philosophy that developed within the people of government and industry who did the work. As individuals, they came to be true professionals playing together as a team. And they came to know, perhaps unconsciously, that success would evade them unless they played together as a team with completely objective impartiality and with complete purity of ethics.

Now you may scoff and say that such lofty idealism is impossible in the real world of competition for profits. And I will say to you that the word "impossible" no longer has the same finality of meaning that it once had.

The Saturn-Apollo team came to know a "gut feeling" that success would be theirs. They were so confident of success that they invited heads of state from all over the world to witness the launching of Apollo 11. They planned for world-wide TV coverage. They arranged for the personal appearance of the President at the splash-down in the middle of the Pacific. And they planned carnival-style celebrations for a successful voyage — all months in advance of the event. They did it again with Apollo 12 even more perfectly than before.

Do you think for a moment that Saturn-Apollo people would make arrangements like that for a foolhardy venture? No, their confidence, their gut feeling (although accompanied by some butterflies), came from their faith in that lofty idealism. (It cannot get rid of butterflies but it can sure make them fly in formation.) After all, can any human undertaking really succeed if it is controlled in the least by foolish pride, bias, avarice, deceit, or prodigality?

Saturn-Apollo was an elegant exercise of a trio: technology, management, and idealism. Its technology is being documented and disseminated through the NASA Technology Utilization Program for all who care to look at it. Management techniques are being similarly publicized. Idealism is what the rest of this article is all about.

Management and technology applied with idealism did overcome "impossibility." After all, Saturn did achieve flawless success, on schedule, and at very nearly the cost estimated at the beginning. How many other undertakings, public or private, can have as much said for them?

So now you ask, "That is all very nice, but where are the neat little packages that I can use 'as is' for my problems?" And I must reply, regretfully, that there are none. All I can say is that you will benefit from space technology and management techniques only to the extent that you inform yourselves about them, and develop within yourselves the third element of the trio, a philosophy that is necessary for their wise use. Careful tailoring with completely honest objectivity is required to satisfy each different problem.

Now looking to the future, it is not unreasonable to think of the voyage of Apollo 11 as a "divine revelation." From far out in space, the astronauts showed you a color TV picture of the earth in full compass. It was a case of their space ship looking at yours, and the rules for survival on either of them are the same.

The limited nonreplenishable resources for sustaining human life on earth are no less definite than those that were provided on the Apollo Command Module. Both require stringent stewardship (management, budgeting, and replenishment). Neither can tolerate unthinking despoilation, or waste, or pollution. Neither can afford uncontrolled increases in population, and neither can endure strife, violence, crime, disease, famine, or lack of environmental control. The only outside resource available to both is solar radiation and some of that is bad.

The challenge was given to us long ago as written in Genesis: "Be fruitful and multiply, replenish the earth, and subdue it." Somehow we have chosen to ignore that middle phrase, or we take it to mean replenish it only with people. Moses might well have received an eleventh commandment saying, "Thou shalt not despoil thine earth, nor pollute it, nor consume it, nor do anything to make it unfit for thine everlasting habitation."

Who among you will deny that commandment? (I doubt that it will offend even an out-and-out atheist.) We simply must achieve a balanced ecology — a controlled growth of population, and a planned use and replenishment of our resources or we shall perish ultimately in utter primitive poverty. Our every undertaking must be wisely system engineered and managed — and the system is our total ecology. The task is no more impossible than once was the notion of going to the moon.

Let us consider how things are today and how they might look in the future. The good things of life such as household appliances, automobiles, clothing, etc., that we use with smug pride (before they are paid for) will not long endure. Most of these things were designed deliberately for anti-maintainability, for limited life, and for unreliability and early replacement by something newer but not necessarily better. The supply of spares and servicing skills, by which to extend their life, ranges from inadequate to non-existent. Even those who make a living at the pretense of repair and service are sustained by commissions for selling the new; repair and service of the old is a secondary priority. Is despoilation and waste the only road to profits?

Manufacturers, distributiors, retailers, and advertisers have worked strenuously to push their products onto us users with no more conscience than that of a dope peddler. As a result, we users are addicted to the euphoria of being freed from the labor and drudgery of housekeeping, travel, communication, and environmental control.

It will do no good to condemn anyone for the wasteful and pollutive practices we have followed. It was perhaps a necessary phase for developing a widespread taste for the "high living" made possible through technological growth. But now the foreseeable situation is drastically different.

The old policy of prodigal despoilation and waste must give way to a new policy of serious frugal conservation and replenishment. This does not mean that all must deny themselves profits and the good things of life, but rather that we must profit by wiser use, and even reuse, of our nonreplenishable resources.

The pace of population growth by itself portends market growth that will more than satisfy even the most ambitious manufacturers, marketeers, and advertisers. Even if we can freeze population at present levels, there is still a staggering market potential among those peoples of the earth who have yet to taste the affluence we take for granted in our own country. But now, combine these two, in the face of an ecology with finite limits, and we have a truly stupendous challenge.

The next 2 or 3 decades are crucial. Mankind has a choice of growing ever larger and poorer until war, famine, pestilence, and pollution reduce his numbers to a few who will one day consume all resources and expire in utter primitive poverty, or he can use his wits and self-control to replenish the earth and assure eternal survival with an ever expanding affluence.

The first choice of easy fatalism need not be accepted. The second choice presents a truly fantastic challenge, but surely no more ridiculous than once was the notion of flying to the moon. In either case, the crucial factor is time, and we are fast approaching the point of no return (PNR) when the choice of doom will be made for us unless we begin now to plan for survival.

Manufacturers, marketeers, politicians, advertisers, and consumers take heed! The only road to survival is to abide by an eleventh commandment and to exercise a new order of frugality. Frugality is not mere self-denial and penny-pinching. It is wise and efficient use of materials and energy. It is their salvage, and reuse, and replenishment. It is the elimination of pollution, noise, noxious odors, and waste. It is designing for simplicity, longevity, efficiency, reliability, maintainability, and interchangeability. It is system engineering of functional systems (as we have learned from the Saturn experience) and the total system is our space ship "Earth." It is cost-benefit conscious specification and integration of functional designs for systems, subsystems, and components.

Appliances as we now know them will cease to be nice-to-have added-on conveniences. They can be efficient long-lived elements of integrated functional systems. A refrigerator, for example, intended to keep things cold will not itself discharge waste heat into a kitchen only to be pumped out again by an over-sized air conditioning appliance stuffed into a half-opened window. Such waste of equipment and energy will be unthinkable.

Dwellings as envelopes for human habitation can be designed as integrated systems to achieve that function efficiently and with esthetic satisfaction. Subsystems for heating, cooling, cooking, personal hygiene, etc., can be standardized modules for quick-disconnect, interchangeability, and maintenance.

Water and atmosphere management subsystems can be completely closed-loop and fully regenerative. The idea of using 5 gallons of potable water to wash away a pint of human waste, only to later reprocess the whole mess, will be generally abhorred.

The present complex, expensive, and wasteful systems of underground piping for supply of electricity, gas, water, and for waste disposal can be eliminated. Water, energy supply, and waste disposal can be handled by local neighborhood reprocessing units, and possibly even by individual dwelling units.

Industrial pollution of all forms can be thoroughly controlled so that there will be no need for zoning ordinances. The immediate environs of factories and service businesses can be highly desirable as dwelling sites. This by itself could greatly relieve the people transportation problem.

Palatable food stuffs can be augmented by edibles derived from the seas which receive four-fifths of our solar energy — the only resource coming into our space ship "Earth."

Packaging of consumables can be designed for consumption as edibles, or for salvage and processing into other useful products.

Fibers and fabrics for clothing can be synthetic and salvageable for reprocessing into other products. Cleaning and laundering can be minimum and pollution-free. Styling can be infinite and highly attractive.

Other possibilities are simply endless. The only dependable thing about the future is change. The status quo of building codes, labor union feather bedding, and business as usual will join the horse and the oil lamp as unjustifiable.

We have the technology base now to launch successful attack on these problems, provided we apply a philosophy that gives priority to an eleventh commandment. The Saturn technology and management principles are documented and available to you. The essential idealism for that "gut feeling" for success was documented for all of us long ago in the "good book."

Technology, management, and idealism, the trio for Saturn success! "Who needs them? You do. We all do." We are all astronauts on our own little space ship "Earth."

EDUCATIONAL SYSTEM MANAGEMENT — PREMISES, PROBLEMS, PROGRESS, AND PORTENT

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The American educational establishment is today being shaken by two revolutions. The more well-known of these involves philosophy and is well documented by the press in its frequent descriptions of the many campus battles pitting radical versus conservative, black versus white, student versus administrator, etc. The second of these revolutions is technological in nature and centers around radical changes in: curriculum structure; instructor preparation, assignment, and utilization; scheduling and grading; facility design and utilization; and administrative technique. The following list identifies, for various of these categories of change, some of the following innovations which have resulted from the technological revolution:

1. Curriculum structure — New math, the phonics alphabet, Montessori techniques.

2. Educator preparation — Trainee self-evaluation through use of instant replay, simulation techniques.

3. Grading — Reorganization of schools along ungraded lines, and use of immediate instructional feedback.

4. Scheduling — Computer assistance, provision for instructional periods of variable duration, and use of optimization techniques.

5. Instructor utilization — Multidisciplinary teaching teams, roles as coordinators of learning aids, and prerecorded lectures.

6. Facility design — Modular design, flexible use of space, and learning resource centers.

7. Educational technology — Computer-assisted instruction and multimedia audiovisual systems.

8. Administration — Computer managed instruction, performance evaluation, and management information systems.

The causes of the technological revolution were many. The knowledge explosion made it imperative that new and more efficient means of teaching students be found. Dissatisfaction with the results of the present educational system indicated that a thorough overhaul of the instructional environment was required. Growing pressures from militant teachers, community leaders, and government agencies forced the educational establishment to undertake implementation of more effective and economical methods of teaching and administering students. Provision by the Federal Government of large sums of money aimed at encouraging educational innovations served as a strong motivating factor towards accelerating the introduction of instructional technology into the schools. Lastly, there was recognition of the fact that a requirement existed for true individualization of instruction, and that this need could not be met using traditional classroom training methods.

To provide individualized instruction, it was necessary to develop means for identifying student-learning objectives, to define methods for evaluating student performance, and to improve techniques for selecting and presenting instructional materials. To implement the above, techniques were needed which would permit nonlockstep administration of students, improve planning, and provide more rapid and flexible access to information. This optimization of the administrative aspects of instruction then led to the requirement for systems which would permit shared access to multi-institutional data bases and thus achieve still greater increases in educational effectiveness while obtaining economics of scale.

A multitude of independent research programs were mounted to develop the above set of capabilities. Quite recently, it was recognized that certain of the tools of systems management might have utility in dealing with this set of problems. In this section, three of the principal applications areas are identified within which systems management techniques could be applied to educational problems. These areas are: coordination of instructional program content and pacing for individual students; integration of the many and diverse activities within a single educational institution; and management of the shared operations of numbers of otherwise independent educational institutions.

The technology in the systems management of individualized instructional packages must incorporate the capability for dealing with measurable differences between students. This includes identification of the levels of achievement that each student may be expected to reach, allowance for the rate at which individual students learn, provision for the unique goals and learning styles of individual students, and determination of each student's proposed level of mastery of his subject matter. This in turn is required for each educational objective, the specification of the level of proficiency the student is to obtain, and the level of retention he would be expected to maintain over a given period of time. Individualized instruction further calls for the student to directly or indirectly select his own materials, proceed at his own pace, and evaluate his own progress. The systems management of all of the above is relatively sophisticated when viewed from the position of dealing with the needs of a single student. The marrying of the independent programs of large numbers of students into a cohesive and comprehensive administrative package is obviously orders of magnitude more difficult to achieve successfully, and represents the second of the three applications areas of system management in education.

Systems attempting to marry individualized student programs (which it must be added are not yet broadly typical in that they represent the ultimate in individualized instruction) are being developed in growing numbers. Most involve the use of data management systems organized into six basic subsystems: pupil management; curriculum and instruction management; personnel management; property management; fiscal management; and administrative support.

In the past, educational data processing systems were transactionally oriented, with independent files being established for data in each of the above six areas. The emphasis was placed solely on servicing traditional administrative functions. Today, however, such systems are being developed to serve as "information utilities," from which multitudes of users at a given institution can cull interrelated data drawn from many files. Such systems are intended to serve the needs of administrators, teachers, counselors, curriculum developers, and students; e. g., in several systems in use today, students working independently generate detailed achievement records in answer to diagnostic questions posed by the system. Their records are stored in the data management system and are used by the counselor to identify any given student's learning problems by the curriculum developer to assess summaries of the learning experiences of groups of students, by instructors to determine each student's progress and level of understanding, by librarians to update student information need profiles, and by administrators to monitor and schedule individualized study programs in an ungraded environment.

The acceptance of the concept of integrated data systems led logically to the concept of serving all units in the educational hierarchy and sharing various educational activities through increased use of information networks. This type of system illustrates the third kind of applications area wherein systems management can be of use in education. A few of the activities in higher education which benefit from data sharing across institutional boundaries in terms of greater effectiveness and/or economies include libraries, computer sciences, closed-circuit radio and TV, communications engineering, audiovisual sciences, education and health research, administration, instruction, information retrieval, and clinical health operations.

The growth in use of educational technology of all types has been phenomenal in recent years, albeit the field is in its infancy, and the problems of implementation are many. Computer systems are presently in use at thousands of educational institutions, serving as instructors, medical patients, administrators, counselors, and planners.

Individualized instructional packages are beginning to be implemented at school systems around the country. Some of these individually prescribed instructional packages are permitting elementary and even preschool children to select and manage their own educational programs.

Information utility systems for the public schools are underway at state levels in at least eight states, with many other states planning to follow. An organization exists exclusively for the Chief School Data Processing Officers of every state and territory, which has as its principal goal the implementation of standardized information utility systems throughout all of the public schools of this nation.

Another organization is at least 5 years downstream in the development of a multiuniversity information network serving, at last count, 42 institutional members in 23 states. At least 12 smaller information networks either now exist or are in planning.

A question to be asked is whether educational technology represents simply a fad of low durability in our schools. Every indication available today shows this not to be the case. A recent study disclosed that 25 percent of all U.S. schools now employ educational technology, while less than 2 percent of these schools have dropped an innovation once introduced. Twenty eight percent of the nation's schools have adopted some form of administrative EDP system. Less than 1 percent later dropped this capability. Fifteen percent of the schools surveyed have used some form of simulation devices or materials; under 0.1 percent of these have discontinued its use.

The traditional role of instructors will change because of the introduction of educational technology and systems management into the schools.

Typically, the instructor's role was to "tell" the student in the form of open-loop lectures, "show" him by means of demonstrations, and "test" him through spasmodically given noncomprehensive quizzes. With the advent of the educational revolution, this will all change. The principal new roles will be for the instructor to serve as systems manager in the coordination of the presentation of diverse self-instructional learning materials, and for him to act as consultant to his students concerning any problems or special interests they may have with respect to the subjects and materials covered. The future role may also include authorship of his own optimized instructional packages which will then be recorded for presentation at some later time.

One school worthy of note in that it is already implementing many of the above principles is Oral Roberts University. At Oral Roberts, 130 student stations are provided; 100 of these use CRT displays, earphones, and speakers. A daily program directory is posted at each terminal. Extensive audiovisual facilities are provided for the author of materials, but a technical staff keeps this material from getting in the way of the teaching process. The teacher defines course objectives and identifies what the curriculum will say. Then the planners at the Learning Resources Center that are skilled in radio, TV, art, and multimedia information retrieval recommend various supporting educational materials. The instructor interweaves these materials into his lecture at his discretion and the whole is recorded on videotape for later viewing. The teacher upon completion of his course planning then is available full time to tutor his students as required.

A somewhat similar system is in use at Oklahoma Christian College. This system uses dial-accessed tape recordings to instruct some 850 students, each of which has an individual learning carrel assigned to him. The taped lectures of his professors are augmented by slides or filmstrip projectors available from the library. Many of the lectures require feedback actively from the listener in terms of entries in workbooks. Course material is available 16 hours per day, and carrels are located in the students own dormitory, as are sublibraries carrying frequently requested materials. It is worthy of note that, following implementation of this system, the use of library materials has doubled.

The Naval Academy at Annapolis has approached the problem of optimizing education by applying the systems approach to course design. At the Academy, instructional program content and media are being defined by asking the question, "What do I wish to teach and what are the best possible methods and devices for teaching it?" By way of comparison, most other instructional technology systems underway today started with their conclusion and worked backwards to their problem; e.g., "Given that computer assisted instruction shall be used to teach a given subject, how can this best be accomplished?"

Since the technology above seems so obvious and appropriate to the learning situation, it is significant to note that most applications today are wholly research in nature. Numerous problems make this so — problems which affect the administrator, the instructor, and industry.

The administrator is concerned with the fact that little is known on how students really learn and therefore how effective such technology actually really will prove to be. He feels he cannot trust industry, which was responsible for overselling him on the dubious merits of programmed instruction, teaching machines, and obsolete computers. He knows that educational technology is expensive in costs of authorship of materials, implementation, and maintenance. He is aware that such systems become obsolete rapidly. The availability of federal funds to pay for such systems is unlikely and local funds are impossible to obtain. His school facilities are not suited to accept technology physically, and his mandated schedule of operation precludes economic usage of such systems. He does not know who will provide teaching materials for these systems or if he can make use of good materials present in someone else's system.

The teacher's problems in accepting technology are different from those of the administrator. His principal fear is that this technology will cost him his job. He is afraid that if he is forced to use it and runs into troubles demonstrating its use to students, he will be thought of as being incompetent. He worries that students will be depersonalized if taught through technology. Quite often, the instructor is ignorant of what technology can do for him and is therefore afraid of its powers. The instructor feels that the engineer who designs such systems has little appreciation for the necessity for top quality instructional materials and thinks in terms of hardware design alone. He is apprehensive that under branching techniques of programmed instruction (the basic principle of computer-assisted instruction) the student can be exposed to as little as 20 percent of the materials to be taught, and that the making of such a decision is at the discretion of a machine.

The industrialist's problems center on the fact that he does not know how to function economically in the school environment. His customers at the public school level consist of some 20 000 fractionated school systems, all with their own beliefs as to what capabilities systems should incorporate. The industrialist wonders whether to first manufacture equipment in large quantities to lower per unit costs and then worry about finding customers and writing instructional programs, or vice versa. He is concerned about the penchant of schools to either fail to state objectives altogether or to use non-quantifiable educational goals such as produce better citizens, which leaves him without a proper set of design criteria. He is troubled by the incompatibility of systems in the field today, by the lack of progress towards standardization, and by the difficulties of serving large numbers of users in real-time. He is faced with problems of superimposing technology on schools physically and organizationally unequipped to accept it, and concerned over the costs of marketing a single expensive and sophisticated system to a number of schools that have never before agreed upon anything simple, nevertheless something this complex.

Despite all of the above problems, most agree that it is still eminently worthwhile to keep pushing towards implementation of educational systems. Truly individualized instruction is invaluable to the student. Normally, difficult students being taught by machine have been shown to benefit because the technology forestalls their being subjected to the possible negative judgment of their peers. Course content can be continually improved over time as practical experience with it is gained, unlike the always unique classroom lecturing mode of instruction. The effect of the master teacher can be multiplied. Experiences impossible to provide via lecture can be simulated simply and repeatedly to provide inexpensive real-life practical experience. Students exposed to these techniques are entranced by it and invariably over long time periods want to continue its use long past the end of the regular school day. Through the use of technology, administration is greatly aided in its job of running the schools. It serves as a forcing factor towards eventual performance evaluation. In the long run it will prove less expensive than standard means for teaching and it provides a solid grounding in skills usually unattainable by traditional classroom techniques.

There are many trends at work affecting the future course of educational technology — trends within the school, government, industry, and the community.

There will be increasing engineering of the total environment of education within the schools. The trend will be away from the rigid controls of today into an almost fully individualized environment. Performance evaluation locally and nationally will become a reality as schools begin to adjust to the concept of feedback, objectives, and systems management.

Low-cost design of schools will become widespread as a result of the growing cost of education in general. These new facilities will increasingly be designed to provide for the flexible use of modular spaces. Satellites and cable TV will be used to cut communications costs of multisite integrated systems. Standardized computer-assisted-instruction systems which guide the author in preparing his course, as well as the student in taking it, will gradually become commonplace. Computer terminal costs will be cut greatly by using standard TV sets as output devices. Schools will increasingly move into the commercial data processing field with the offering of its machines to industry for a fee during hours in which the schools would not otherwise make good use of them. Computer systems will be developed which couple moderately-equipped localized processing capability with centralized and remotely located large systems possessing huge shared data bases containing occasionally needed information. Information utilities and networks will link virtually all of the nation's educational institutions.

Industry will move more and more into the role of instructor as performance contracting with industry by the schools becomes more common. Incentive and penalty clauses will be written into instructional contracts, first for the teaching of more difficult students and courses, later for the staples of school curriculums. Public school systems will eventually be forced to become competitive with industry to survive.

The Federal Government will take more and more of local control from the schools with respect to factors holding back the spread and standardization of technology systems. Federal funds will begin to be made available on a continuing incentive basis rather than by grant.

The most rapid growth area in education will be in that afforded by commercial institutions to the community resident for his leisure. The average citizen has educational interests which conventional school systems do not satisfy because of lack of appropriate course content, schedule, or location.

Because of the recognition of the consumer as a direct customer of education and educational products, more and more companies will move into commercial educational ventures. Many will propose use of the portable or disc cassette as the instrument of training, and some will propose use of the videotape cassette which will play through home TV sets. Persons will be increasingly able to stay current in the events of significance within their professional field by listening to recorded highlights of interest rather than reading publications. Computer-assisted instruction will be made available via a telephone line in the home.

In conclusion, it seems obvious as a result of all of the above that the technological revolution will soon reach into our schools, colleges, and home, and will affect every aspect of our society. The challenge to systems management in the next decade is to further the integration of the various new educational devices, methods, and techniques leading towards the configuration of a maximally effective, responsive, and economic system for learning.

SYSTEM MANAGEMENT APPLIED TO WATER RESOURCE DEVELOPMENT PLANNING[4]

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The invitation to participate in this joint professional meeting on systems management is welcomed by the Department of Water Resources of the State of California. The Department, too, has long been interested in quality control for much of its construction program and recognizes the value of system engineering as a management tool to achieve that objective.

In the planning of water resource developments in the State of California, the system management concept goes back many years. In reviewing the history of this concept and its application first let me define what system concept is, as used in this paper. Simply stated, it is the best possible arrangement of a series of controlled actions to produce a desired objective.

In engineering activities, this could be: (1) the design of a circuit for optimum color reproduction in a TV set; (2) the modification of an existing power train in a motor vehicle to achieve maximum power from nonleaded gasoline; (3) the design of a structural frame for a 100-story building to resist major earthquakes and hurricanes; (4) the excavation of tunnels and conduits without the use of wood or steel supports; (5) the pouring of mass concrete continuously for concrete dams, bridge abutments, launching pads, etc.; (6) planning the best possible water resource development for California; and (7) planning the optimum schedule for contruction of a water project.

Obviously, each of the overall systems need to be subdivided into subsystems, each to be analyzed on its own merits. In making the analysis on its own merits, various restraints of course apply which vary from one subsystem to another.

[4]Presented at the Joint Professional Meeting, Systems Management Symposium, Disneyland Hotel, April 2, 1970.

In civil engineering, we can approach a systems management concept through the use of the Critical Path Method (CPM) scheduling diagrams, supported by computer analyses which are sensitive to the least-cost component. This has worked well for design and construction activities.

I would like to turn the clock back to the 1950's and explain how the Department of Water Resources of the State of California utilized system management to create the California Water Plan by interfacing a series of hydrologic basin subsystems into a master system for the development of water resources throughout the entire State.

Specifically, the objective was to develop a statewide plan for the control, protection, conservation, and distribution of California's most vital resource, water, for the immediate future and for ultimate optimum development. The first step was to divide the problem resolving into three major subsystems.

An inventory of data on sources, quantities, and characteristics of water in California was made. The inventory was completed and published in 1951, designated Bulletin 1. In 1955, Bulletin 2 showing the present and ultimate requirements for water throughout the State was published by the State. The interfacing of Bulletins 1 and 2 was accomplished through Bulletin 3, published by the Department in 1957, creating the comprehensive master plan called the California Water Plan.

Within each of the three major subsystems there were 11 additional subsystems consisting of a hydrologic basin. Each basin, usually a river and its tributary watershed, was developed as a system to optimize the resource development and then the 11 were interfaced to produce an optimum result for the State as a complete entity.

To give you some idea of the optimum result which was achieved by the three subsystem analyses that produced the California Water Plan, you should know that the plan is designed to include or supplement, rather than to supersede, existing water resource development works and does not interfere with existing rights to the use of water. The objective in the formulation of the California Water Plan has been to provide a logical basis for future administration of the water resources of the State and for coordination of the efforts of all entities engaged in the planning, construction, and operation of water development projects to the end that maximum benefit to all areas and peoples of the State may ultimately be achieved.

The California Water Plan includes local works to meet local needs in all portions of the State. It further includes the California Aqueduct System, an unprecedented system of major works to redistribute excess waters from the northern area of surplus to the area of deficiency throughout the State. The Plan gives consideration to water conservation, reclamation, flood control and flood protection, the use of water for agriculture, domestic, municipal, and industrial purposes, hydroelectric power development, salinity control and protection of the quality of fresh waters, navigation, drainage, and to the interests of fish, wildlife, and recreation. It contemplates the conjunctive operation of surface and ground water reservoirs, which operation will be essential to regulation of the large amounts of water ultimately to be involved.

The very magnitude of the task involved in formulation of the California Water Plan was such that detailed economic and financial analyses could not be undertaken in this initial phase of the investigation. At this stage of its development (1957), the plan had to be regarded as no more than a broad and flexible pattern into which future definite projects could be integrated in an orderly fashion.

The practical result of the publication of Bulletin 3 was the authorization by the State Legislature in 1959 by passage of the Burns-Porter Act for the construction and operation of what is known as the State Water Project. A brief description of the project follows later in this section. Staying for the moment with the planning concept, the next planning step after publication of Bulletin 3 occurred approximately 10 years later.

In the mid-60's the Department of Water Resources reevaluated the total state water resource development system as set forth in Bulletin 3. The data and information were published in Bulletin 160-66 released in 1966. In Bulletin 160, the 11 hydrological areas of Bulletin 3 were rearranged somewhat. They are shown, as used in Bulletin 160, in Figure 13 (Fig. 4 of Bulletin 160). Each of these hydrologic areas is a subsystem complete in itself.

Figure 14 (Fig. 6 of Bulletin 160) shows how data for the 11 hydrologic areas were interfaced for the entire State. The lower portion of Figure 14 charts the estimated growth from 1960 to 2020 of net water requirements for each hydrologic study area and the total net water requirements for the State by years to 2020. For comparison, bar charts are shown for the population, land use, and applied water requirements.

As an example of the detail in each of the subsystems, Figure 15 (Fig. 13 from Bulletin 160-66) shows for the south coastal study area the

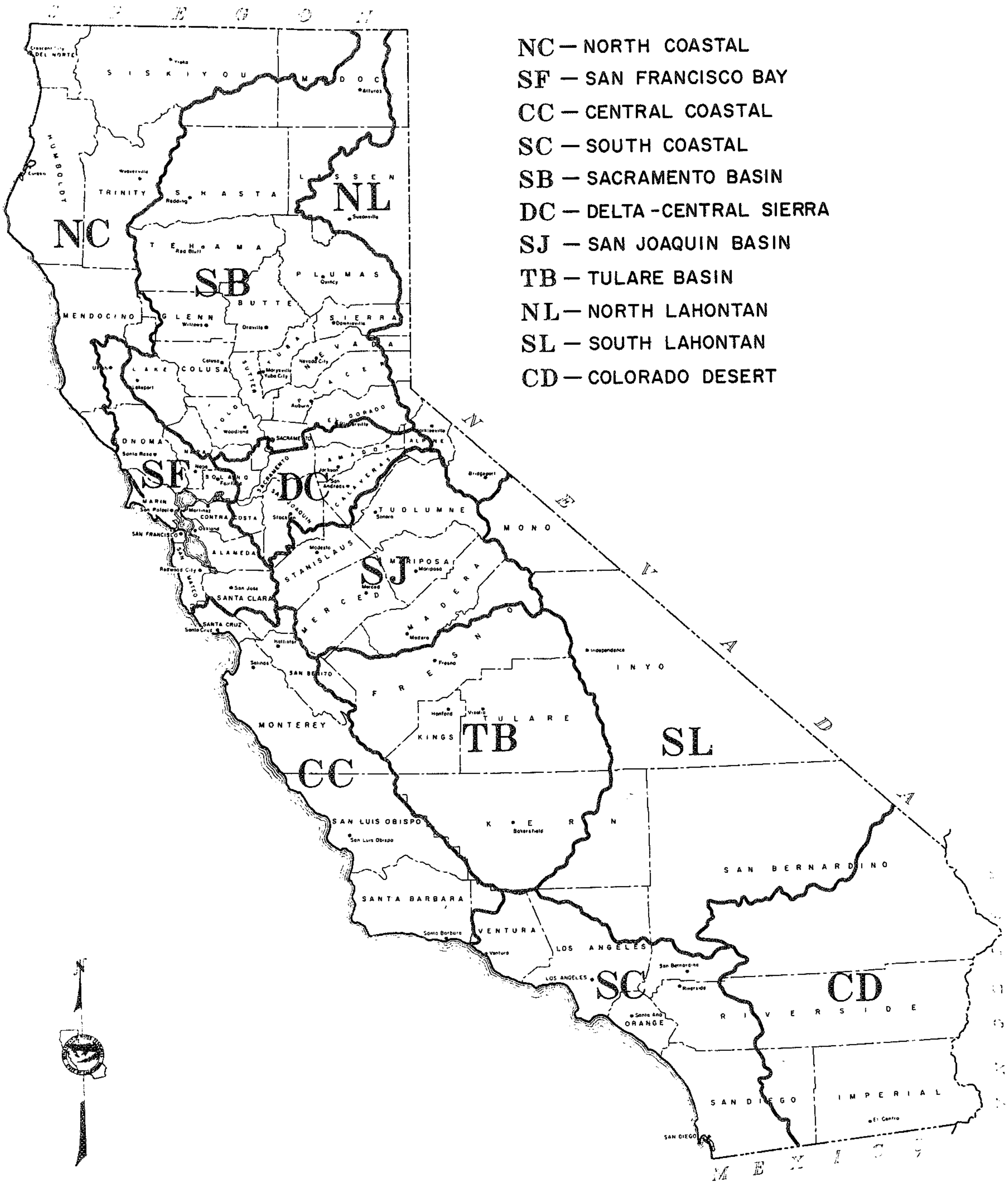


Figure 13. Hydrologic study areas of California

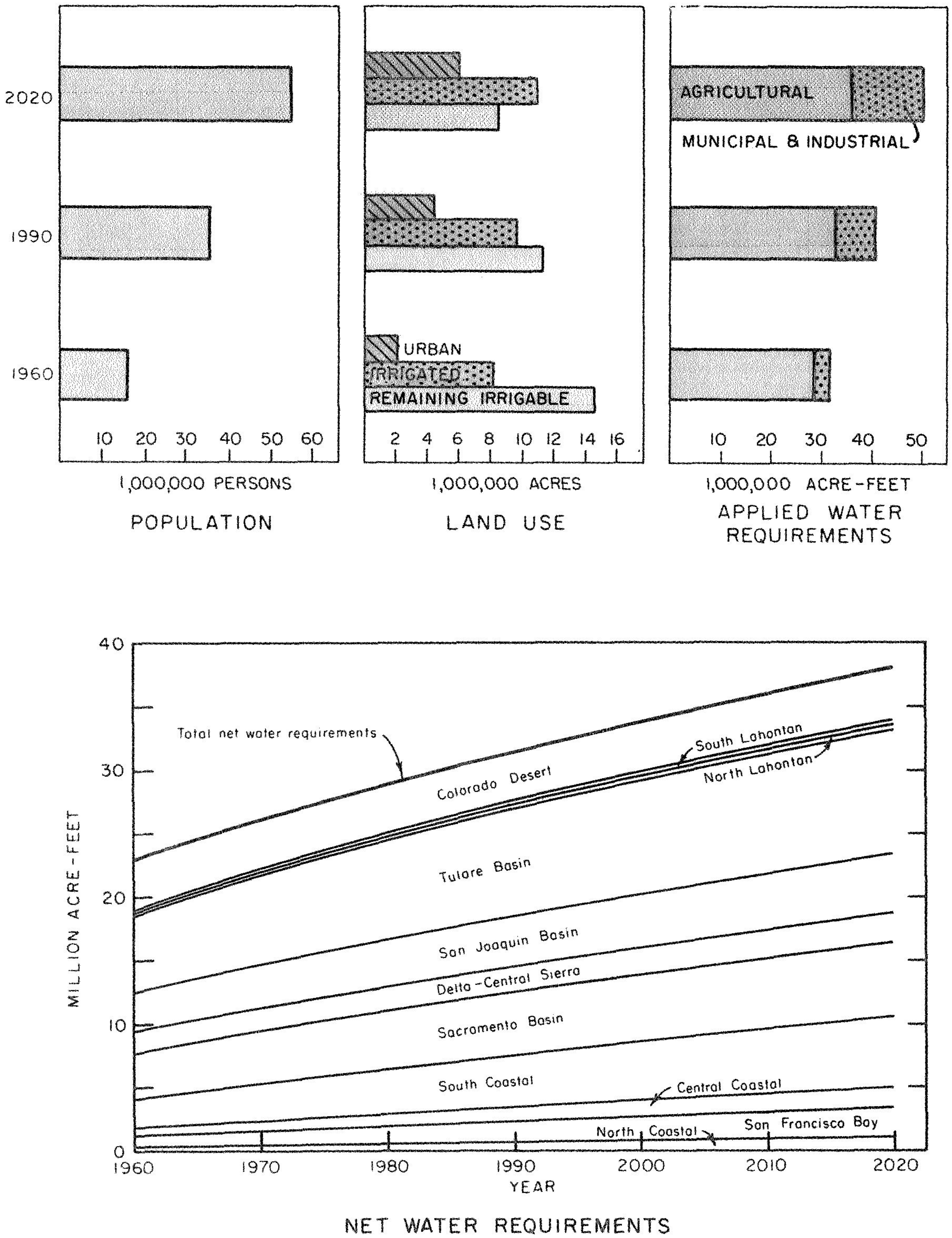
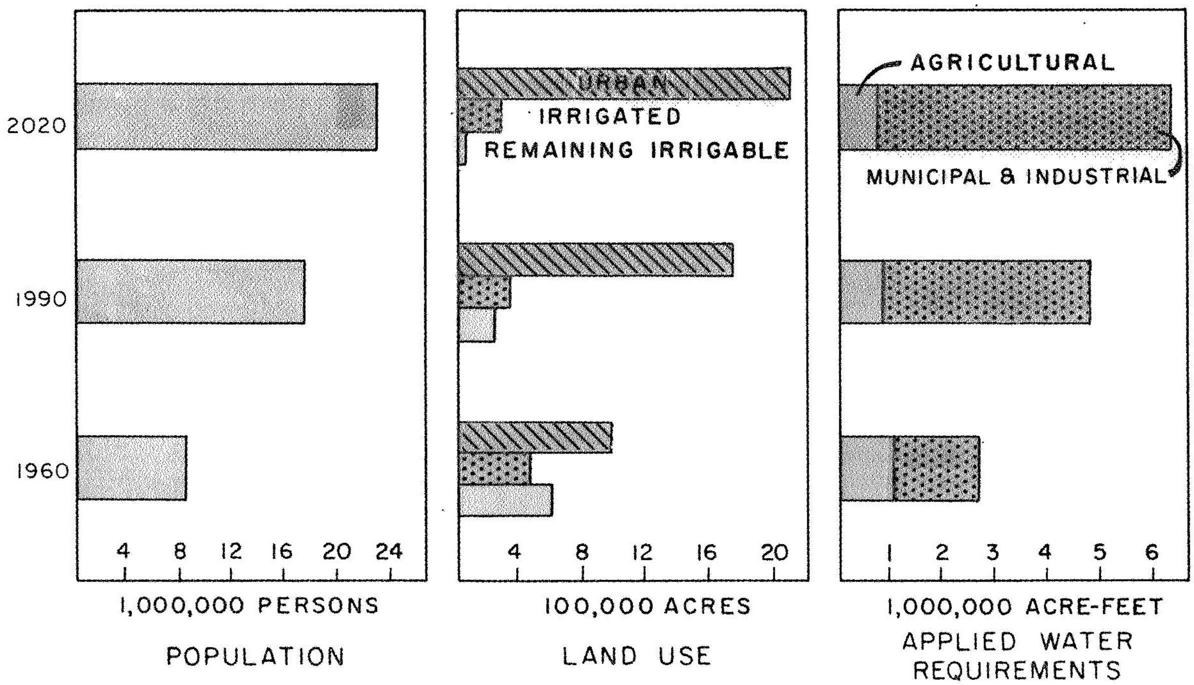


Figure 14. Statewide totals



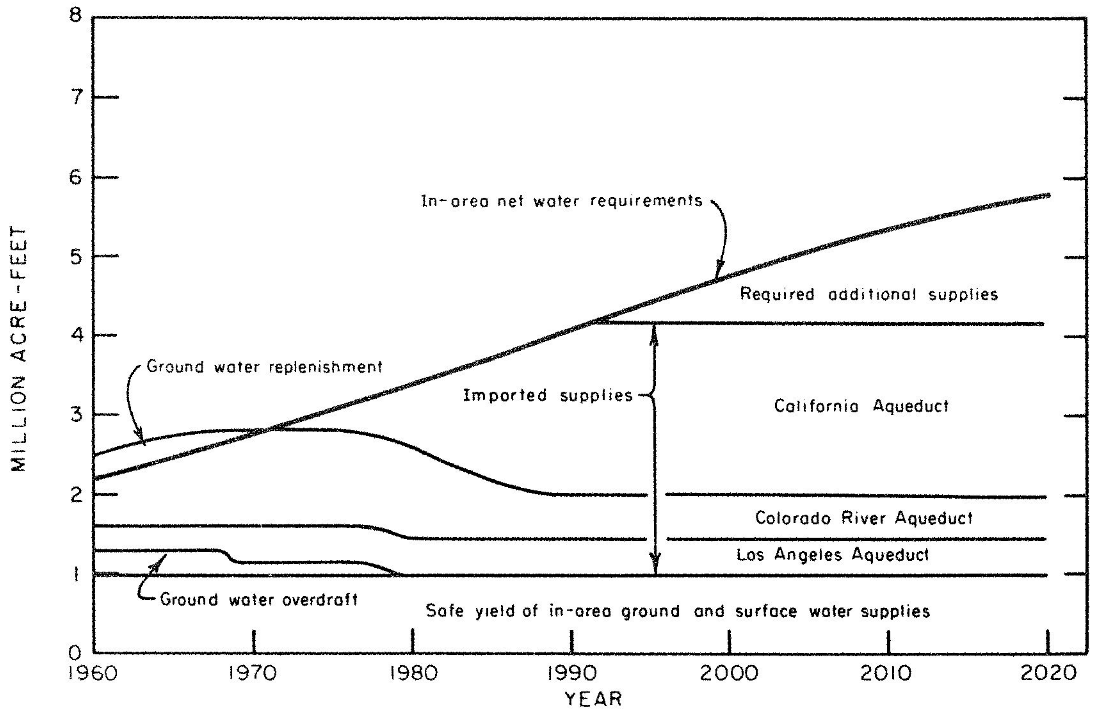


Figure 15. South coastal hydrologic study area

requirements of water in terms of million acre-feet from the years 1960 to 2020 and sources of waters. Bar charts for population, land use, and applied water requirements are also shown. The graph, bar chart, and map analysis was developed in the same way for each of the other 10 hydrographic subsystems.

Figure 16 is a pictorial representation of the intrastate water transfers projected for the 1990 level of development. This is a system of water transfers that will be in effect when the State Water Project will be operating at full capacity in 1990. The heavy line connecting the several hydrologic areas reflects the influence of the State Water Project.

What is the State Water Project? The principal purpose of the Project is to redistribute surplus water supplies throughout the State to places of need much as shown in the graphic presentation on Figure 16. It was authorized as previously mentioned in the Burns-Porter Act of 1959, based on the technical information in Bulletin 3. Financing has been provided from several sources, the most important of which is a general obligation bond issue of $1.75 billion approved by the voters in 1960. Major construction of the Project started in 1962 when a contract was awarded for the massive Oroville Dam in Northern California on the Feather River. Construction has proceeded apace ever since. The extent of the Project appears in Figure 17.

The Oroville complex on the Feather River consists, in addition to Oroville Dam, of an underground powerplant, recreational facilities, and flood control provisions. The control of floods on the Feather River, which have in the past created much downstream havoc, is a major purpose of the Project. A subsidiary power development about 10 miles below Oroville Dam is a part of the overall development. The generation capacity by use of a pump storage scheme, at Oroville, is 725 000 kilowatts.

In addition to the Feather River complex at Oroville in the high upper Sierra, the Department has constructed three small reservoirs which are primarily for recreation use. They also supply a small amount of water for irrigation and domestic use. Two more small reservoirs have been authorized and will be built some time in the future when the necessity for their construction for recreation becomes evident.

Water released from the Oroville Reservoir pass downstream into the Sacramento River and into the Delta formed by the southward flow of the Sacramento and northward flow of the San Joaquin. The Consumnes, Stanislaus, and Mokelumne Rivers also flow into the Delta. At the south end of the Delta, the State has constructed a pumping plant, lifting water 250 feet into the

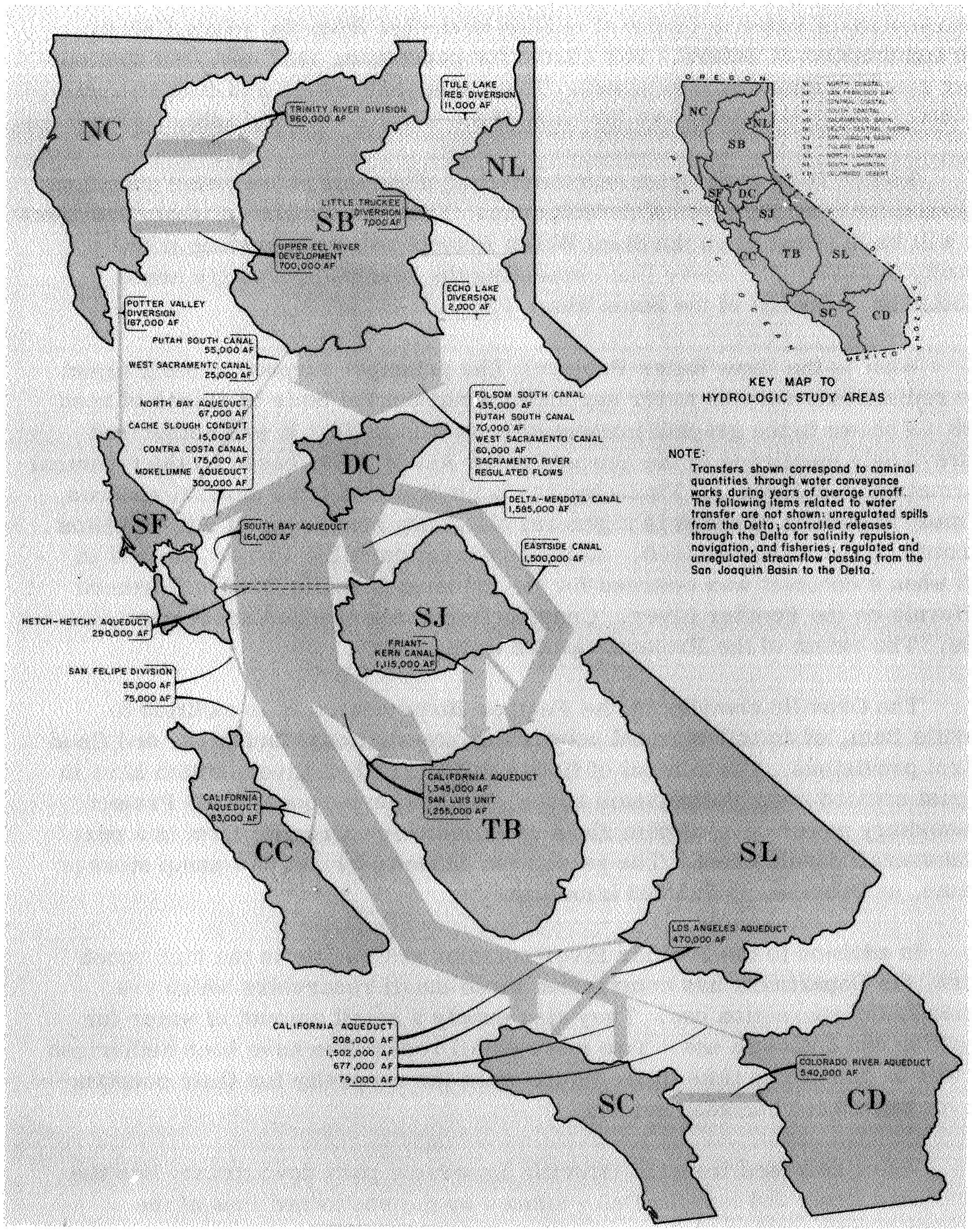


Figure 16. Projected intrastate water transfers for 1990 level of development

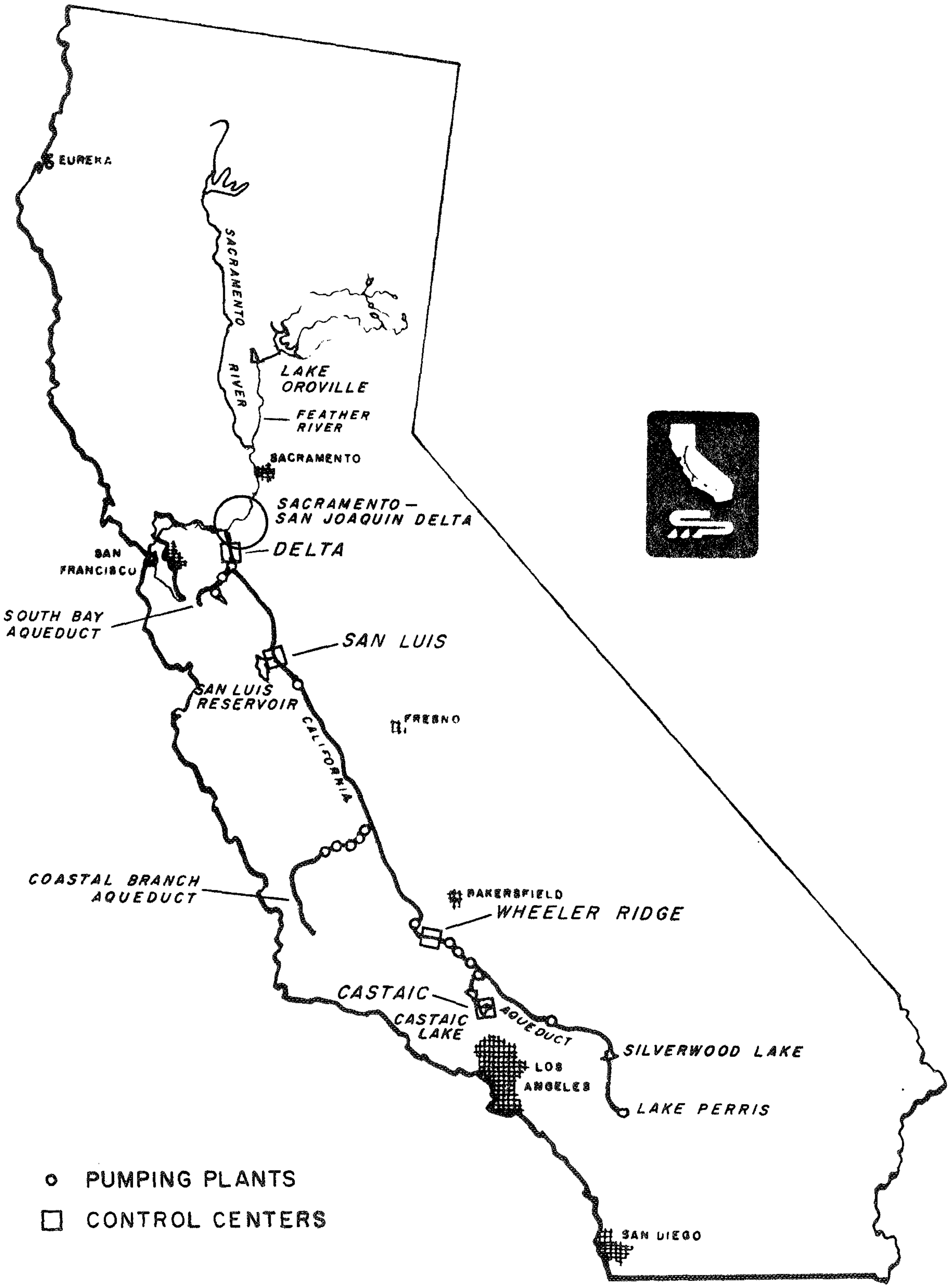


Figure 17. The California State Water Project

California Aqueduct which extends down the west side of the San Joaquin Valley to a point near Taft where it swings east, crossing Wheeler Ridge continuing to the Edmonston pumping plant at the north face of the Tehachapi Mountains approximately 35 miles southeast of the City of Bakersfield.

Construction of this aqueduct system, including four intermediate pumping stations, has been substantially completed except for the last 50 miles still under construction. It has been in use for the last 2 years delivering irrigation water as far south as the Buena Vista Pumping Plant located just north of Taft. The remainder of the system across the southern part of the San Joaquin Valley will be available for use later this calendar year.

At the Tehachapi Mountains, elevation 1200 feet, the Department is constructing the Edmonston Pumping Plant. This highhead pumping plant will lift 4400 fps^3 approximately 2000 feet up the north face of the mountain. The Tehachapi mountain range is crossed by an 8-mile tunnel system that delivers water into Antelope Valley at abut 3100 feet above sea level. Here the aqueduct system divides into two parts. One part, known as the West Branch, follows Interstate 5 and old Highway 99 in open aqueduct to a place called Pyramid where a 7-mile tunnel is being constructed to bring water into Castaic Lake also now under construction. Castaic is a few miles north of the San Fernando Valley. It will provide a terminal basin for delivery of water to the Metropolitan Water District of Southern California and to two other local water districts in the area.

The second part is the East Branch which travels 100 miles along the south side of the Antelope Valley and the Mojave Desert area terminating at the Cedar Springs Dam now under construction 15 miles north of the City of San Bernardino. A tunnel through the San Bernardino Mountains will bring the water from the Cedar Springs Reservoir through a powerplant at Devil Canyon and on through a 30-mile pipeline down to the eastern terminal of the project at Perris Reservoir near the town of Perris just east of March Field.

Backing up the aqueduct system we have a branch that takes off from the Delta and serves Livermore Valley and the City of San Jose. This branch has been in operation since 1962 for Livermore Valley and since 1965 for San Jose. A small aqueduct on the north side of the Delta has been constructed to serve the County and City of Napa.

The main aqueduct going down the west side of the Valley contains a major pumping and storage facility at San Luis, which is near the City of Los Banos. The San Luis Reservoir stores winter flows and has a capacity of 2 100 000 acre-feet. This reservoir and its associated pumping powerplant has been in operation for about 2 years. Construction is scheduled so that water can be delivered to the Edmonston Pumping Plant about mid-1971 and initial deliveries to the Metropolitan Water District from the Castaic Terminal Reservoir should begin late in 1971. Also, at the Castaic Reservoir, the Los Angeles Department of Water and Power is constructing a large powerplant of 1 200 000-kilowatt capacity which will utilize aqueduct water for the creation of peaking power, much needed in the Los Angeles urban area. The advantages of hydroelectric power are that it does not pollute either the air or the water nor does it destroy the resource. The State is sharing in the cost and benefits of this power facility.

The construction of the aqueduct system across the south side of the Antelope Valley and the Mojave Desert area is proceeding rapidly. A pump lift at Pearblossom which is east of the City of Palmdale is also under construction. It is estimated that water will be in the Cedar Springs Reservoir, called Lake Silverwood, by early 1972 and that water deliveries will be possible through the tunnel to Devil Canyon. It is not expected, however, that Perris Dam will be completed until sometime in 1973.

Also, over the West Branch, one major reservoir remains to be constructed, the Pyramid Reservoir required to develop maximum head on the Castaic Powerplant and to provide supplemental storage for the water system.

Recreation has always been one of the main purposes of the State Water Project. In the high Sierra and at Oroville, water-oriented recreation is already available. Down south, four new lakes will be created in the next few years. Two of them, Pyramid and Lake Silverwood, will have on-shore facilities built by the State but operated by the U.S. Forest Service. Castaic Lake will be operated by the Recreation Department of Los Angeles County, and Perris Reservoir recreational facilities will be built and operated by the State Department of Parks and Recreation. Collectively, these four State Water Project recreation area should supply a lot of swimming, boating, fishing, water skiing, and camping close to home for thousands of outdoor enthusiasts of the south.

I should mention also the situation regarding the financing of the Project. The cost of the Project has been underwritten by some 31 water districts of which Metropolitan Water District of Southern California is the largest. All of these districts have contracted with the State to repay the cost of the project on schedules required to amortize the bond issues. Because of the high interest rates, it has not been possible to dispose of approximately $600 million worth of water bonds which remain to be sold.

We should remember that the water bonds constitute slightly less than half the bonds involved in Proposition 7. $600 million out of $1.3 billion Cal-Vet and school bonds make up most of the rest. It is necessary that the State have authority to sell the bonds above the present fixed statutory interest rate limit of 5 percent. If the State Water Project is to be completed on time, an affirmative vote on Proposition 7 on June 2 is essential.

Should the passage of Proposition 7 fail so that the interest rate is not increased and the bond market continues at something like its present high level, it could be possible that the burden of repaying the costs of the bonds already sold would become an obligation of all the taxpayers of the State with a substantial increase in their tax burden for many years to come. It will cost the taxpayers nothing to vote yes on Proposition 7 for the water bonds.

SYSTEMS CONSIDERATION IN COASTAL ZONE MANAGEMENT[5]

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Introduction

The kaleidoscopic nature of the diversity of problems which we must face in the management of our national resources is readily apparent within the coastal zone. It is within this geographic area that we are focusing our efforts to gain some semblance of control over the rapidity of demographic and technological change which characterizes our present society.

Coastal Zone Legislation

Current legislation, creating coastal zone authorities, is before Congress following the recommendations of the Marine Commission in its January, 1969, report "Our Nation and the Sea" (Chapter 3, pages 49-81 and 269-270). Senators Magnuson and Hart proposed that "it is the policy of Congress to preserve, protect, develop, and where possible, to restore the resources of the Nation's coastal zone through comprehensive and coordinated long-range planning and management" (Senate Bill No. 2802, 91st Congress, First Session).

Federal programs are intended to empower and fund State commissions, agencies, or other governmental entities in an effort "designed to promote balanced development, and produce the maximum benefit for society from such coastal areas" (ibid). Several states are structuring organizations to implement these programs and accommodate a wide variety of beneficial uses through coastal land acquisition, master plans, zoning regulations, and development projects.

[5]This article was prepared for publication from a talk given April 1970, conference on "Systems Management in the 70's," NASA. It is the first presentation in a series of three talks to be given on Coastal Zone Management.

Different Needs

The scope and nature of our coastal zone problems are different for each of the several states. In Alaska, the coastal zone provides logistical support for the interior development of the region. In certain other states, as in most underdeveloped countries of the world, the coastal zone may also contribute logistical support for the recovery or processing of offshore resources. The motivation is economic. The emphasis is on development. In California, there are internal, demographic, pressures against the coastal zone. Current emphasis is on conservation. Preservation of social amenities is the incentive.

However, this is too broad a generalization. California is also ranked seventh among the major powers in the world in gross national product. Some degree of industrial development within the coastal zone is inevitable and logistical support must be provided to maintain water-borne commerce. California has also taken a leading position in oceanography. The technology which permits recovery of offshore resources effectively extends California's economic potential beyond its geographic borders. Prohibitions or excessive taxes on the coastal investment marshalled to recover or process these resources would redirect the value added or created to other jurisdictions — perhaps in closer proximity to the resource. The oceans lend themselves to this diverting approach more than does a similar form of operation on land.

It is also deceptive to think of the California coast line as a linear extension of a problem that is primarily centered within areas of metropolitan concentration. Southern California and the San Francisco Bay area are major population centers within the coastal zone. Even within these urban areas, there are considerable differences in the scope and nature of coastal problems. The Bay Area, for example, is concerned with closed circuit, estuarian problems, while Southern California is involved in open ocean systems. Essential differences can be found throughout the United States where urban concentrations impinge on other coastal zones.

Diversity of Uses

Coastal lands are geographically limited or static, while pressures for a diversity of uses are increasing in a dynamic fashion. The multiplicity of pressures from a variety of special interests and environmental considerations include:

1. Committed uses — Determined by topographic or oceanographic features, national security, etc.

2. Conflicting uses — Such as offshore waste disposal versus marine recreation, and other mutually exclusive coastal activities.

3. Competitive uses — Which are compatible in nature, but require management for balanced applications or the establishment of priorities for allocation.

4. Compatible uses — Which are interdependent or together form a symbiotic system to the exclusion of other considerations.

Economics of Scarcity

The expanding requirements for use of a geographically limited resource are creating the economics of scarcity within the coastal zone. The economics of coastal zone management suggests the need to expand the available inventory. This can be accomplished in three ways: (1) create new land, (2) relocate certain facilities in the interior, and (3) provide access to other coastal areas beyond the centers of concentration.

Historically, man has reclaimed land from the sea. The Dutch have reclaimed over 1.6 million acres. The Venetians built one of the world's most beautiful cities offshore. Marine sciences and technology have increased the capability of offshore construction. New methods and equipment have made it possible to create additional land values with extensions to the existing coastline, the erection of platforms and offshore structures, and the construction of offshore islands. Six islands (Rincon, Esther, and the THUMS complex) have been developed off the coast of California. With Malibu land going for $2000 per ocean front foot, the economics of scarcity will continue to make this alternative an investment opportunity.

Much of our coastal land has been preempted for facilities that could equally serve their purpose within interior areas. These include such installations as marshalling yards, parking lots, warehousing, etc. Lack of adequate transportation, inefficient traffic patterns, and limited access to the environment have misdirected land use where social/economic considerations would have dictated alternative courses. Using vertical construction in industrial concentrations and moving some functions offshore (e.g., offshore terminals) would also add to the available land inventory.

Our technology provides additional ways of alleviating some of the pressure against the coastal zone and effectively adding to the inventory. Where we have the problem of allocating or utilizing scarce resources, we must discover an acceptable means of diminishing this problem and accommodating multiple use by moving down the scale of controversy from conflicting to competing interests, to compatible use, and to the optimum, a form of symbiotic relationship. Examples of this might include the reprocessing of waste disposal so as not to contaminate recreational beaches; or the use of heated waters from industrial cooling processes, what is termed thermal pollution, to support aquiculture.

Allocating the Remainder

Topographic or oceanographic characteristics could commit certain areas to specific uses or at least preclude a number of alternatives. Waves dashing against a rocky cliff contribute to the scenic value of an area and may commit it to some form of low density use. Extremely cold water or dangerous surf conditions inhibit recreational development. Commercial ports require some degree of protection and adequate water depths.

Although environmental factors may commit a portion of the coastline to serve certain functions, and technology may increase the compatibility of other applications, while careful planning contributes to the available inventory by moving some functions in, out, or up — we still must eventually get down to the nitty-gritty of deciding how to allocate the remainder between competing uses to meet the objective of producing the maximum benefit for society from such coastal areas.

Coastal Development

The coastal zone has long provided economic benefits to the nation and to the immediate areas that have grown up around its commercial ports and harbors. Our firm conducted an extensive survey of the current level of investment in ocean-oriented industries and marine activities. We found that $60.6 billion was invested in marine commerce, ports and harbors, and support for ocean transportation. An additional $34.9 billion was invested in coastal development in support of other ocean endeavors for a total investment, as of 1968-69, of $95.5 billion. This is projected to increase to a level of $168.2 billion by 1980.

The total current level of investment for all ocean-oriented industries and marine activities, including surface and subsurface systems, is estimated to be $165.3 billion. This investment has an annual yield/benefit from such things as fishing, petroleum, recreation, etc., of $18.8 billion. We have no measure of the through-put value; i.e., the multiplier effect that these expenditures have as a contribution to the nation's GNP, but the resulting figure must be substantial.

Increasing investment to support the projected growth opportunities for offshore industries, marine commerce and recreation, and the need to provide public services through additional facilities for power plants, waste disposal, etc., will result in further demands against limited coastal lands. Changing technologies in marine transportation (giant tankers, containerships, and vessels with new configurations, such as hydrofoils) will require new types of installations. Offshore terminals (pipelines, airports, and causeways) will all dramatically affect the economics of coastal zone management.

Environment

As this investment continues to flow into the coastal zone, it will further impinge upon the environment. The ecology has already been affected as estuarian areas are dredged for small boat harbors or commercial fisheries deplete a species and interdict the food chain. The normal supply of beach sands has been curtailed by flood control projects or the littoral movement interrupted by nearshore structures. Pollutants from coastal cities or agricultural drainage, oil spills, and offshore waste disposal corrupt coastal waters.

No one intentionally pollutes or destroys the environment. We all contribute, in some manner or means, to depreciation of the states of nature, either through inadvertence of thoughtlessness. By our very presence in the coastal zone, we detract from the aesthetics of the area. Conservationists wage a continuing battle to preserve scenic and historical areas from further encroachment.

We know so little about the ocean and energy sources that maintain the balance of our environment or affect temperature regimes, weather, and other phenomna, that we must be somewhat circumspect in the ways in which we develop this resource. We have already discovered the serious consequences of interfering in other environmental systems and any future changes in the coastal zone should be closely monitored to avoid subsequent diseconomies.

Low-Density Uses

Maintaining a balance between low- or high-density uses of the coastal zone is the fulcrum of major controversy and part of the problem in defining the objective, maximum benefit for society. At one end of the spectrum are conservationists who would put a moratorium on all further development. At the other end are exploiters who would act without thought of future consequences. Fortunately, the majority lie somewhere between theses extremes and the area of contention is narrowed to the use of the coastal zone for recreational purposes or industrial/commercial enterprises.

Local jurisdictions are in effective possession of coastal lands, access routes, and resources. Zoning regulations and variances are a determining factor in land-use allocation. These jurisdictions primarily rely on tax revenues to provide necessary services. The highest possible economic yield from coastal-zone properties is an incentive for capital investment. Any attempt to allocate coastal resources between low- or high-density uses will have to consider a reallocation of tax-based revenue as a means of compensation and incentive for a local area to maintain or redirect appropriate land use for low-density, low-yield applications. Redistribution of tax revenues could be predicated on a formula that gives consideration to linear coastline, population density, administrative fees equated to the investment in trust, and cost of maintaining the environmental integrity of the area.

Government

There are various political theories on how we should proceed toward our objective of managing resources within the coastal zone. Basically, opinion is divided on the necessity of having the program directed from some central, governmental source, or the advantages of having it emanate from local entities. It is the age-old problem of subordinating the rights of the individual to the rights of the state.

Those who support the centralized source are concerned about the immediacy of our environmental problems, systems requirements, and, quite frankly, have little confidence that the individual has the capacity to act in the best interests of the many. Perhaps they are right. As we see where we are now and where we are heading, there is an obvious need to reconcile conflicting interests. However, where should the coastal zone authority be located, in Washington, D.C., at the State, county, or city level of local government? The regional concept of government is currently popular, and there are those who would create a superintervening agency or regional boards to implement a coastal-zone program. If so, how many regional boards and how would they be integrated? There are innumerable philosophical questions to be answered and operational problems to be resolved. No matter which format is eventually accepted, the democratic process must be sustained.

Systems Management

Many of our current problems can be traced, not to technology, but to the scientific methods which created that technology. As a recent article[6] pointed out, our highly specialized concentration within narrowing fields of competence has achieved remarkable progress, but it has also fragmented our industries, segmented our bureaucracy, and confined our thought processes to singular objectives. This "tunnel vision" has had side effects, diseconomies, and other consequences that are detrimental to the total system — not the least of which is our environment. "In a modern society, the principle of fragmentation, outrunning the principle of unity, is producing a higher and higher degree of disorder and disutility" (ibid).

As we have already seen, the concept of coastal-zone management involves some very complex and perplexing problems. What we primarily need is a system for organizing all of the basic data. We have to know where we are now before we can even contemplate initiating changes. We need an inventory of coastal-zone land and use patterns; topographic, oceanographic, and other environmental data; measures of social/economic needs; and whatever else will assist us in our decision making processes. Next, we need statements of policy on what our overall objectives should be, with some rather specific criteria against which we can measure our performance. Finally, we require some degree of flexibility so that we can recognize the need for changes to meet contingencies.

The task which we have set for ourselves is so overwhelming that we must delegate the responsibility for planning to individuals or groups to be incorporated into programs by local entities, such as cities or counties. Local participation can be encouraged through various management tools — taxes, subsidies, incentives, etc. There should be an obligation assigned to those who propose changes to analyze the probable effects and provide a means to measure the net contribution.

[6] "How to Think About the Environment," Fortune Magazine, February, 1970.

These local programs should be collated into regional presentations to be certified by some administrative State agency as meeting the overriding criteria representative of policy statements. Variance procedures should be established. Finally, the coastal-zone management program should be approved by the State Legislature with an adequate budget to provide interconnecting services, such as utilities or access roads and other supplementary needs. Funding should be in an order of priority, contributing the maximum benefit to society.

Conclusion

We are committed to some form of directed effort — a process of conscious decision-making called resource management — to intervene in highly diversified, complex, and interdependent systems. Where once we relied upon some overriding synthesis of purpose — a mystic concept of manifest destiny — to eventually reconcile specialized and divergent interests toward the common good, we are now substituting collective judgment to coordinate individual action. Coastal-zone management may yet provide a means to accommodate the quantitative needs of our economy within the more simplistic needs of a qualitative society.

CROWINING OF A QUEEN[7,8]

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City of Long Beach, Long Beach, Calif.

The Spanish conquistadors conquered California from the Indians and claimed it for their own in the year 1769. Some 15 years later, as Manuel Nieto (former Spanish soldier) rode across his Rancho Los Nietos, he could little foresee that his 40 square miles of cattle ranch would one day be known as Long Beach, California. The present-day custodians of the city, on behalf of the people, have much more than problems of cattle pastures to occupy them. The elected city council and the appointed city manager have the responsiblity for the current operations of the city as well as for future planning.

The haphazard growth and expansion of urban areas have led to problems of great magnitude. Some of these are immediate and urgent while others are concerned with the distant future. It is necessary that all of them be dealt with realistically in terms of planning resources, management, and implementation. The City of Long Beach has attempted to deal with its own present and long-range problems by a most practical and at the same time most imaginative approach. The 1911 arrangement with the State of California permitted the city to retain certain tidelands oil money in a trust fund, the use of which was generally restricted to development of areas of Maritime nature. Meanwhile, the city went ahead with a plan to utilize a portion of the tidelands trust funds to develop a marine recreational facility including a museum in the area of Pier J in the Long Beach Harbor District.

After an in-depth study of the problems of education, housing, transportation, urban blight, and industrial decline, the city manager, with approval of the city council, embarked on a program to provide organized planning leading to a solution of these problems.

The result of this study was the recommendation by the Planning Department that certain components of the urban structure needed improvement to provide a viable city system. These included:

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[7]"Focus on Long Beach," League of Women Voters.

[8]"The Queen Mary, Past, Present, and Future." by Leo J. Greene.

1. Airport expansion.
2. Waterfront redevelopment and expansion.
3. Downtown business center renewal.
4. Highway extension.
5. Harbor expansion.
6. Urban redevelopment.
7. General beautification.

As with any constructive effort, it is necessary to have some central group acting as an advancing force. In this case, the city council sought to implement some or all the elements of the required program by normal administrative means. The general response to this effort might be best described as indifferent. Something other than normal procedures had to be followed to achieve the desired goals.

After a dramatic and bold decision on the part of City Manager, John R. Mansell, and concurrence by the city council, an exchange of property took place in December 1967. Her Royal Majesty's Ship Queen Mary (Fig. 18) now belonged to the City of Long Beach. The city now owned the largest and the most famous passenger ship in the world. A ship which is as long as the Empire State Building is high, and whose tonnage is equal to six Long Beach class missile cruisers. An acquisition which in fact is a floating city having some of the most charming and relaxing public rooms to be found anywhere in the world. In essence, the City of Long Beach had captured, after hot competive bidding, the tool which would enable them to embark on an uplift program of vast scope and impact.

The Queen Mary Project consists of essentially two parts: (1) the conversion of the ship, and (2) the preparation of site capable of supporting its operation. A new city department was created to accomplish these two results and was aptly named the Queen Mary Department. The city recruited Rear Admiral John J. Fee, USN, for the position of Department Director, and the project began.

Upon completion of work to the hull below the waterline at the Long Beach Naval Shipyard and major rip-out of over 20 000 tons of structure and machinery, a contract was awarded to the Smith-Amelco Corporation of Compton, California, for accomplishment of the basic conversion. This corporation was formed as a joint venture for this project and had no prior ship conversion experience. The conversion was to take place at Pier E in Terminal Island. Temporary facilities for personnel, offices, and parking as well as for heavy equipment were provided at this location. Upon completion of the conversion, the ship will be towed to its permanent berth at Pier J in Long Beach. There, an entire complex is being prepared to support all of its requirements.

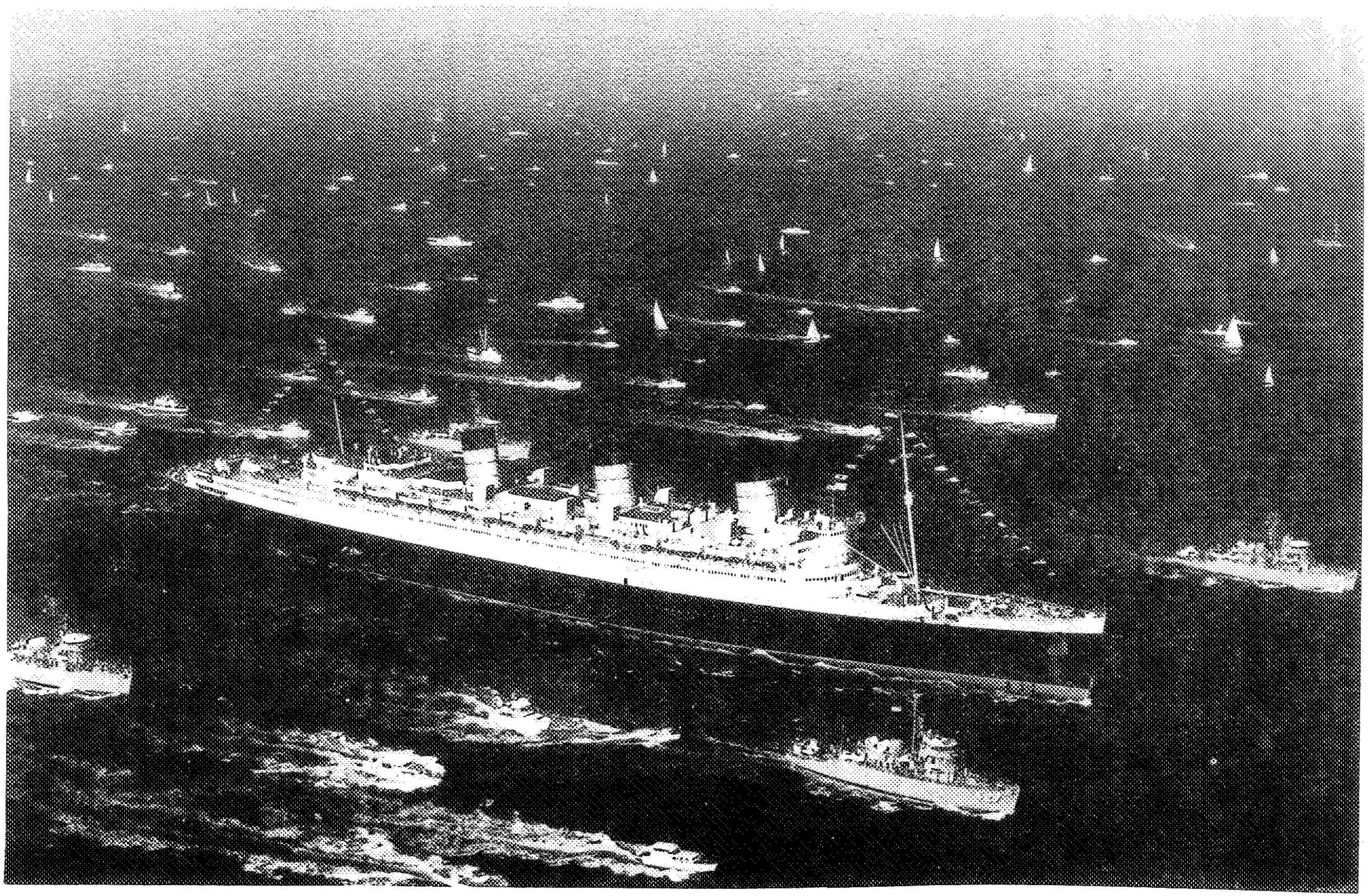

Figure 18. The ship "Queen Mary."

The Queen Mary Department retained Harco Engineering Corporation of Terminal Island, California, to provide engineering review and other services which have included program management, liaison, and special studies. After the program had been in progress for some months, the department retained the Advanced Planning Technology Associated Corporation to provide coordination administration and other management support services.

The principal conversion participants are the City of Long Beach, owners of the ship; the Museum of the Sea Corporation, operators of a museum in the lower half of the ship; Diners/Queen Mary Corporation, Master Lessee of the upper half of the ship for commercial purposes; and the conversion contractor. There are over 75 major conversion interface elements. Several of the more important interfaces are:

1. Long Beach City Council.
2. Long Beach City Manager.
3. State of California State Lands Commission.
4. State of California Museum Foundation.
5. Long Beach City Engineer.
6. Long Beach Department of Building and Safety.
7. Conversion Contractor — Smith-Amelco Corporation.
8. Master Lessee — Diners/Queen Mary Corporation.
9. Museum of the Sea and its Consultant, the Living Sea Corporation (Jacques Yves Cousteau).
10. Southern California Edison Company.
11. General Telephone Company.
12. Central Plant Operator — Ohio Energy Systems.
13. Site Planning — Killingsworth and Brady/Niskian.
14. The California State Legislature.

A control center has been set up for the purpose of providing a means whereby any or all elements could be brought together as required to effect proper interface. In addition, a means was provided for tracking progress and identifying problems. The ship was divided into segments by decks as well as vertical sections and each subspace designated with an identifying code. Coordinators were assigned to permanent tasks on the basis of interface elements as well as by functional systems.

All participants in the conversion were brought together and briefed on the operation of the interface system and urged to make full use of the services offered.

Upon receipt of a problem, a serially numbered Work Task Assignment Order is prepared, logged, and issued to the responsible coordinator. It is then his responsibility to notify the interfacing elements and if necessary bring them together for a solution. The Work Task Assignment Order cannot be logged out until a resolution of the item has been made.

A weekly Program Management Group Meeting is held to resolve upper level problems and to identify the 10 most urgent tasks. The participants at this meeting from the Queen Mary Department are the Director, Assistant Director, Contract Administrator, Engineering Review Manager, and Coordination Manager. The conversion contractor's Project Coordinator, Project Engineer, and Contract Administrator complete the group. Decisions reached at this meeting result in the issuance of confirming documents or Work Task Assignments.

All incoming and outgoing documents, including drawings processed by the department, are passed through the Document Control Center where every document is identified, logged, and distributed either to the addressee or in conformance with a standard distribution guide.

The conversion contractor is required to provide regular CPM printouts to the department Master Scheduler for analysis and approval. Problem areas identified by him are brought to the attention of the Program Management Group members. The Master Scheduler is also responsible for control of the Space/System Completion record. This provides identification of completion of every system on the ship as it affects each individual space. A specially prepared record form as well as general arrangement plans of each deck of the ship are used as tools in tracking these items.

There have been many problems in the course of the conversion to-date. The decision to have engineering and production performed concurrently by the conversion contractor has resulted in the requirement that working drawings be developed with severe time constraints. This has also had the effect of causing major impact on production schedules and costs when changes, no matter how minor, are required. The response to this has been a strong effort by the department to prohibit all changes unless needed for safety or to make systems workable.

It should be explained at this point that the ship has been officially designated as a floating structure. The structure, which was originally built to the rules of Lloyds of London, must now conform to the Long Beach Code and other applicable National, State, and local codes to qualify for a certificate of occupancy. Affected by this are the electrical, fluid, environmental, and structural systems. The entire ship is being air-conditioned and completely rewired. Chilled water and steam are to be supplied from a central power plant being built 0.5 mile away.

The contract specifications are of the design rather than the performance type and this coupled with contract drawings which were intended for guidance in some cases, and compliance in others, has led to innumerable questions of interpretation. The single largest source of interface problems has been a result of this situation.

Unfamiliarity with the peculiarities of ship construction resulted in the building trades workmen having to adjust to the fact that almost all working surfaces were curved. The use of plumb bobs and carpenter's levels was prevented by the slight changes in heel and trim on the ship. Every dimension had to be calculated from some known point and transferred to the working area. This situation led to the contractor's retaining shipwrights as advisers to the construction crews. Union agreements prevent the use of maritime workers aboard the ship.

The site interface has encompassed the fields of highway development, parking, landscaping, traffic control, and underground service utilities. The parking lot has been designed for 4000 visitor's cars and 500 employee vehicles. More than 50 acres of land will be directly used to support the Queen Mary operations. This land has been filled in from the adjacent waters, and as the Queen Mary Project expands in the future, additional land will be reclaimed as necessary. All utilities are to be placed below ground and spare pipes, conduits, and vaults have been provided to take care of growth during the anticipated life cycle.

Numerous tradeoff studies were made with regard to the selection of the optimum traffic handling system. The final configuration provides integrated flow compatible with local and State Highway systems.

The concern for safety has necessitated the development of evacuation and damage control plans, emergency lighting systems and close liaison with the City Fire, Police, Building, and Safety Departments. Provision has been made for connection to fire apparatus on both the land and water sides of the ship. A ship-wide temperature and smoke detection system terminates in a control room console which also contains closed-circuit television and automatic bilge flooding alarms. The firemain and sprinkler systems have been upgraded to provide maximum protection in accordance with modern standards.

Special training programs are being developed for the personnel responsible for the security of the thousands of people in their care. The entire field of safety has been given top priority by the department in all phases of both the conversion and future operations.

The Master Lessee, the Diners/Queen Mary Corporation, has responsibility for operation of the upper half of the ship for commerical purposes. These will include numerous shops, restaurants, night clubs, and a 400-room hotel and a convention hall which accommodates 1500 people. The large banquet hall accommodates 1000 people. The city insisted that the original decor of the ship be retained and this requirement has been made part of the contracts with all participants.

The most exciting part of the conversion is the unfolding of the design of the Museum of the Sea which occupies the lower half of the ship. The Living Sea Corporation headed by Captain Jacques Yves Cousteau is the designer of the museum. The Cousteau Designs deal imaginatively with the most advanced techniques for communicating to the visitor the wonder that is the sea. The themes include such fields as aquatic food chains, communication, propulsion, procreation, and the growing problem of pollution. The Cousteau Concepts require the construction of a museum environment which will create the maximum interplay between the visitors and the exhibits. Entire decks have been removed and extensive structural work accomplished to allow the museum to attain this goal.

A nostalgic part of the museum will be that portion illustrating the history of the Queen Mary. One completely restored engine room, a steering gear room, and both shaft alleys will be open to the public. One propeller has been retained and completely enclosed so that visitors may view it from outside the hull. The slowly rotating propeller will be part of the power train exhibit.

All marketing surveys indicate that the ship will embark on a new career more illustrious than it has ever known. The ship will be visited by more people in 1 year than it carried in its entire history. When this takes place, the city will have attained one of its basic aims; the attraction to Long Beach of people, business, and the catalyst required for the achievement of the remaining system goals.

The "Crowning of the Queen" does not refer to the Queen Mary itself but the addition of the Queen Mary to the tiara worn by the Queen City, Long Beach, California.

CAN SYSTEMS MANAGEMENT REALLY SAVE MEDICINE?

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The entire medical industry today finds itself caught in an economic squeeze. For once, one's good health was defined as being able to put in a full day's work. Now, good health means being free of all physical, psychic, and social complaints. Once, doctors were looked to as the last resort in matters of health. Now, they are frequently looked to as a first thought not only in matters of health but in many of the arts and skills of living once ministered to by grandmother, friends, and the local minister. The supply of doctors has not kept up with this burgeoning need. Hospital employees have organized and forced marked raises in their salaries. These raises have been reflected by similar increases in the salaries of various doctor's assistants inside and outside of the hospital. Even technology has added to this fiscal pressure. Therapeutic methods are now available that do wonderful things but at equally wonderful costs. Once, expensive procedures could be funded by overcharging on cheaper, more common procedures. Radiology departments could support expensive cineradiographic units by slightly overcharging on chest x-rays. With third-party financing, each procedure is now being cost accounted, making such practices less available. For the insured, this is of little significance, but it is of great significance to the uninsured. The natural resultant of these pressures has been an increase in medical costs.

Because of this, all of those people involved with the supply of medical services (suppliers and users) are searching for ways to reduce these costs, but so far about all that has been gaining much governmental support is the control of medical charges through various legislative schemes. On the other hand, the medical service suppliers have turned to systems technology for salvation. To date, it does not appear that they have achieved much in terms of savings. What has been going on? Where does the problem lie? What is needed?

Systems technology grew beyond the speculative stage with the introduction of electrocardiographic diagnosis by computer. Here, electrocardiograms are fed to the computer from magnetic tape. The computer identifies and measures key parameters on each electrocardiogram and compares these with known normal and abnormal values. Based upon these comparisons, a diagnosis is produced. The biggest problem here is to identify these parameters in each electrocardiogram.

Recently, a small portable computer has been produced which measures the desired parameters of the electrocardiogram and displays these so that they can be jotted down by a technician.

Physicians and hospitals have been looking to technology for a solution to their data problems. Medical and hospital office data procedures are not too unique and thus do not pose a great problem. The big problems lie in the handling of patient data (histories, physicals, orders, nurses' notes, etc.). Not only does patient data constitute the biggest volume, but it also poses a number of knotty problems. One special-purpose approach to this problem has just become commercially available. The Corbin Farnsworth Division of Smith Kline Instruments has incorporated a small computer into their coronary and intensive-care monitoring systems. This allows one to set alarm limits and note 24-hour trends in any of the parameters monitored. In addition, it stores orders for each patient that it can display at command. Further, nursing notes can be written into the system. For all of this, one uses a series of pushbuttons, first to call the index, then to call a specific procedure and, finally, to obtain a glossary of responses. Thus, the doctor's orders and the nurse's statements are selected from a previously stored group of phrases and terms. Nonstandard notes and orders can be entered by typewriter. New terms and phrases can be entered into memory for future reference by this same technique.

A more energetic approach has been under study by Lockheed for sometime now. This system is not as yet involved in monitoring but only in data handling. Here, all of the presentations are made to the physician on a TV screen. He responds by using a light pen. Thus, when he activates the system with his personal key, a list of his patients presently in the hospital is projected on the screen. He can then select the patient he wishes to discuss. Next, he is presented with a number of choices of what he might do for that patient; e.g., write orders, write a history and/or physical, or make a progress report. Though typed entries are possible with such a system, they are discouraged, and stereotyped responses are provided to handle most circumstances.

Some of the exciting possibilities that such a system promises, in addition to a reduction in hospital paperwork, is the automation of patient logistics (setting up various appointments, calling up supplies based directly upon the doctor's orders, ordering and controlling drugs, etc.). For such a system to realize its greatest potential, all of the hospitals and doctors in the United States could be interconnected. Thus, when a patient enters a hospital, his entire past medical record could be called into the hospital from a central storage area. A similar access would be available to outside physicians.

Another system getting attention today is the automated physical examination. The leader in this has been the Kaiser Hospital in Oakland, California. Here, a portion of a history, various physical measurements, and laboratory tests are done. The results are entered into a computer in a semi-automated manner. From this, a final report is written which not only presents all of the findings but also tags those which lie beyond normal limits.

For several years now we have been studying the automatic controls of therapeutic agents. Specifically, we have directed our attention to the control of blood pressure. A tube is placed into an artery from which we measure blood pressure. A second tube is placed into a vein through which a drug is administered. This drug will increase blood pressure as a function of its injection rate. It sounds like a simple control problem hardly requiring a sophisticated system for solution. This is not the case though. The patient's response to the drug (gain) and the delay between a change in the drug rate and a change in the patient's response are nonexplicitly time variable. The patient's gain can vary by several hundred percent in a few minutes. The delay varies less dramatically for a given individual, but even it can vary slowly over longer periods of time. When one changes drugs or patients, these parameters can also show variation. We have approached the solution to this problem by using adaptive control schemes. So far our results have been very encouraging.

A most-recent development has been the entry of systems theoreticians into the area of hospital design and operation. Stochastic models of the flow of patients through a hospital have been developed. Studies are continuing to evaluate the cost consequences as well as the health consequences of following a given therapeutic course. Similar models are being proposed to aid in medical diagnosis. Here, symptoms and signs are fed in, and the program suggests a series of possible diagnoses and further tests, all based upon the statistics that pertain at that moment. When the results of the suggested tests are obtained, the computer responds with a new list of possible diagnoses, hopefully narrowed from the earlier one. Weights can be given each choice along the decision tree so that diagnoses can be arrived at with minimum cost to the patient in money and morbidity.

Your imaginations, better than mine, can build upon these brief descriptions to suggest other systems that may help the medical industry. But will they? I have been leading you along with a noncritical discussion of some of the things going on in medical technology to set the stage for what I really want to say.

Beware of technologists bearing gifts! Do not be misled by the few superficial successes that have been realized to date. We are still novices in the systems approach to medical practice. Except for some very isolated exceptions, technology has not led to great savings for medicine, and to date, experiments in computer technology have amounted to little more than mechanized bookkeeping. In terms of the examples given here, the automatic reading of electrocardiograms requires more technician time than nonautomatic techniques. In addition, the abnormal records also have to be reviewed by a physician. Furthermore, these systems produce a fairly large percentage of false-positive results which must also be checked by a physician.

In the case of automated hospital data systems, there is a tremendous communication problem that arises between man and machine. Much of the clinical data which require filing are written in prose not lending itself well to storage in a computer. In any event, the data must be laboriously entered. The Lockheed scheme represents one of the most novel ways of bridging the communication gap, but even it has yet to meet with universal acceptance. Automated physical examinations are far from physical examinations. All of those procedures that can be done by nonphysicians are grouped in one place and done in assembly line fashion. Much of the physical remains to be done later by the physician.

Using systems models in hospital planning is certainly better than what exists presently; i.e., little true planning at all. Despite this, such planning has yet to be proven. The costs associated with a given state are hard to determine. Different doctors do things differently. Indeed, different hospitals do things differently; so more that likely many retrospective studies will be required before such techniques will have predictive planning value. There is also the problem that each state may not be pure. What are the therapeutic costs for the treatment of a plain diabetic versus those for a nervous diabetic. This is a grossly nonlinear system and even knowing the cost of therapy for a diabetic and a nervous patient will not help. One cannot add the cost of the care for these two patients to find the cost for a patient with both diseases. Additivity does not hold here. Further, one cannot just determine what one doctor would order to treat a diabetic to evaluate the cost of diabetic therapy, but rather a study of a large group of physicians' habits must be pursued.

Despite all of this, it does not take the knowledge of a sophisticated systems theory to lead one to suspect that there is something wrong when he realizes that about 70 percent of all patient visits to the doctor are for relatively common uncomplicated easily diagnosed problems, yet the current trend in medicine is to produce about 70 percent specialists and 30 percent generalists. To carry these statistics further, 90 percent of doctor patient contacts are for ambulatory patients. Of these, 6 percent are due to trauma, 25 percent are due to chronic disease, and the rest due to acute disease. Of the acute disease, 70 percent are due to one of 10 chief complaints. About the same holds for the 25 percent with chronic disease. Ninety-eight percent of all cases seen with upper abdominal pain have one of six diseases.

For a similar situation in engineering, how would you like to run your staff with Ph.D.'s only from top to bottom, management, planning, design, production, maintenance, etc.? Engineering projects are done by teams with Ph.D.'s, M.S.'s, B.S.'s, and technicians all playing their parts. This is not true in medicine. Even though much of medicine is relatively uncomplicated and routine, the M.D. keeps much of it to himself, frequently resulting in his utter boredom and in higher costs. A lot of this is not, however, the doctor's fault. It results also from legal, social, and administrative pressures. So where do we go? What do we do?

We have to go back to the beginning. We have to start with the medical data systems mentioned earlier, but at first they will not be looked to as a way to save money. They may not even be too sophisticated. For example, a number of studies should be carried out to see if mark-sense check-list physical, history, diagnosis, treatment, and follow-up forms can be developed. One would have to be able to use these forms as efficiently and adequately as the classic prose techniques used today.

Medical students from the moment they enter medical school are taught that everything described by them in the study of a patient must be in descriptive prose. Thus, such a seemingly simple step is actually a revolutionary step. If it can be shown that the mark-sense check-list approach will work, then physicians must be taught to accept this approach. This means changes in medical schools' curriculums as well as the practices of those physicians beyond their training, but to be successful, computer technology must be part of the everyday activities of medicine. To prove that these newer techniques work, parallel work-ups will have to be done using the old and the new technique to see if indeed something is lost (or gained) by the newer approach. As an aside, it might be interesting to see if nonphysicians and computers can use these history forms to gather information as well as trained physicians. Some studies of this latter sort are going on today.

Once this communication gap has been bridged, and computers can get their teeth into all of the data, the important questions can be answered. Studies can be done to evaluate the use of paramedical people at different points in the diagnostic chain. The practices of different physicians, groups, and hospitals can be compared and optimized. In fact, it is inconceivable that anyone would consider proceeding with any particular plans for providing medical care before such studies are made.

I look to the day when the physician will do what he can do best; i.e., gather data while machines will correlate it, post it, and check to make sure things are done when they should be, but this too will require a major revolution. The revolution will not come about easily. The medical schools and major medical centers that should probably lead the way in these areas are frequently crippled by their own administrative structures. The solo private physician in addition is disorganized. Thus, these studies will be difficult at best to do. There will not be many far-reaching technical improvements in medicine without disturbing traditional medical organization. Sources of funds will have to be made available because individual physicians and institutions cannot afford the initial losses in time and cost that such a program would entail. Furthermore, there must be political, legal, and social understanding of the risks and gains that are associated with and hoped for such a project. Physicians cannot be expected to assume the legal risks for such undertakings. All that can be expected is for them to exercise due care. Here is an opportunity for government and medicine to do something truly constructive, something that should not, save for human factors, be unobtainable, something that surely will save lives at all levels. Such a program can be funded with the money saved by not getting involved in imprudent legislative schemes.

I do not know whether systems management can save medicine, but it can certainly help so long as the systems managers are willing to get involved in the unique medical aspects of the problem. I assure you that the problems are not as simply solved as they would appear at first glance.

For those who wish to pursue further the work described earlier in this section, a brief mention of some of the people working in these areas may help. Automatic electrocardiographic analysis has been pioneered by Drs. Hubert V. Pipberger at the V.A. Hospital, Washington, D.C., and Cesar A. Caceres at the U.S.P.H.S. Instrumentation Service Center, George Washington University, Washington, D.C. Dr. Caceres' work has received the greatest attention.

The small special-purpose computer for the automatic measurement of electrocardiographic parameters is produced by Humetics Corporation.

The Medical Information Group could be contacted at Lockheed in Sunnyvale, California, to get further details on what they are doing with medical data systems.

Dr. Morris Collen was the originator of the automated physical examination system at Kaiser Hospital in Oakland, California. If you are interested in hearing more about this type of system from another point of view, you might contact Dr. Hilliard D. Estes at the Palo Alto Medical Clinic in Palo Alto, California. He oversees the automated diagnostic system associated with the Palo Alto Medical Clinic.

Dr. Richard D. Smallwood of the Department of Economic Systems and Electrical Engineering at Stanford University has been involved in hospital modeling. Dr. J. Octo Barnett of the Massachusetts General Hospital and Dr. Alan Ginsberg at the Rand Corporation in Santa Monica, California, among others have been working on problems in machine diagnosis.

For those wishing to get a better feel for the social and administration problems associated with health-care delivery, I would recommend an article by Hagedorn and Dunlap [33].

Mrs. Anne Scitovsky of the Palo Alto Medical Research Foundation in Palo Alto, California, has had a great deal of experience trying to get economic data from standard medical records. Her trials and tribulations have pointed out the need for better medical data systems.

MANAGEMENT INFORMATION SYSTEMS FOR RETAIL INVENTORY MANAGEMENT

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Goals of Retail Inventory Management

The heart of retailing is merchandising, or as many refer to it, inventory management. Inventory management for a retail concern has the following requisites:

1. Accurately forecasting the types and quantities of goods to be sold to the firm's clientele.

2. Ensuring the timely purchase of merchandise and determining the proper assortment batches for the individual selling outlets.

3. Controlling the sales in the selling outlets to produce a desired rate of inventory turnover at an acceptable gross margin.

A primary objective of information systems for retail inventory management, computerized or manual, is to provide data to merchandising personnel so that they can detect trends, readily compare performance against prior established goals, and ascertain the reasons for undue deviations from plan so that remedial actions can be instituted. To be effective in this regard, the development of an information system for inventory management must take into account the nature of the retailer's operations, the merchandising philosophies that guide these activities, and the work habits and preferences of those responsible for inventory management. It is important that these be clearly appreciated by those involved in the design of inventory-management information systems. Otherwise, the reporting programs that are effected may be brilliant in a theoretical sense, but have little bearing upon the true needs and operating modes of the firm.

The Mix of Staple, Fashion, and Big Ticket Items

There are three basic classifications of goods that are sold in retail stores. Each possesses its own set of characteristics. First, let us examine the characteristics of each category, and after having done so, we will explore the significance of such differences to the types of informational requirements for effective inventory management.

Characteristics of Staple Goods

1. Usually represent relatively low-cost items which are purchased frequently by consumers.

2. Life cycle tends to be relatively long, usually at least several years in duration.

3. Life cycles are not particularly volatile.

4. Seasonal sales patterns are basically consistent from year to year, facilitating relatively accurate forecasting of future customer demand.

5. Typically one-to-one inventory replenishment, modified by predictable seasonal sales peaks and lows.

6. Vendor normally maintains stock, and replenishes rather rapidly.

7. Stores order from vendors rather frequently, and in relatively small-order lots.

8. Seasonal carryover of inventory is common, and there is a relatively low markdown percentage.

Characteristics of Fashion Goods

1. Usually purchased frequently by consumers.

2. Higher average price than for staple items.

3. Relatively short life cycle, usually a season or so.

4. Forecasting the acceptance by consumers of new fashion items is risky.

5. Consumer demand for new fashion item can grow very rapidly. Conversely, the demand for a fashion item that had received wide customer acceptance can decline quickly and with little warning.

6. Typically, no carryover of a fashion item to the next season. Substantial markdowns common for unsuccessful fashion items, or those unsold at the end of a season.

7. Limited opportunity for more than one or two sizable reorders after the initial trial order; thus, large orders are typical.

8. Unusually long lead time typically involved for ordering merchandise. Can be up to several months in duration.

9. Due to volatile nature of life cycle, one-to-one replenishment not feasible.

<u>Characteristics of Big Ticket Items</u>

1. The life cycle for a particular item is usually a year or longer.

2. The unit value is usually high, and the unit sales are small.

3. Items often are heavy and bulky.

4. Items usually are sold in a selling outlet from a floor sample, with the delivery of the item to the customer coming from centrally warehoused stock as a rule.

5. Frequent use of special-order selling. After a sale to a customer, the store sends a purchase order to the vendor who then supplies the store with the particular model requested. Customer may have to wait several weeks or months for certain items.

<u>A Store's Merchandise Mix.</u> Some retail concerns basically concentrate upon a single category of merchandise. A supermarket chain, for example, deals predominantly in staple goods. A women's clothing specialty chain such as Joseph Magnin or Judy Shops focuses its merchandising endeavors upon fashion goods. Barker Brothers, a leading furniture chain, is mainly concerned with inventory management for big ticket items.

On the other hand, such general merchandise retailers as the Broadway Department Stores, White Front Stores, or Sears-Roebuck are heavily involved in all three classifications of goods. Thus, the inventory-management information systems needed by the latter-mentioned retailers must be more varied than for the other concerns. A reporting system for inventory management for each category of goods — staples, fashion, and big ticket items — normally has its own set of requirements. In the case of general merchandise retailers selling all three groups, the reporting systems must be designed to permit interfacing with one another so that integrated data flows can be obtained.

Stockkeeping Unit (SKU) Designations. Effective inventory management requires data for dollar control and unit control purposes. Merchandising personnel need to know sales, stock-on-hand position, merchandise on order status, and incoming receipts not only in dollar terms, but also by the characteristics of the commodities. For example, a store does not just send a vendor a purchase order for $500 worth of sweaters. It apportions the order for sweaters among such unit control varibles as style, price line, color, and size. Thus, each individual sweater with its own variation of these factors can be designated as a separate item for unit control purposes. The term usually employed in retailing for this designation is SKU. The following identifying items may be affixed via a label or tag to an item of merchandise in a store.

Department Number	Season Identification
Merchandise Classification Number	Price
Vendor Number	Color
Style Number	Size

A retail concern may not require the same degree of descriptive detail for all items sold by it. At times, color or size information, or perhaps both, may be of little consequence for meaningful inventory management. In others instances, style data may not be of particular pertinence. The value of providing computerized reports containing highly detailed SKU information must be equated, of course, with the cost of data capture and generation. The greater the extent of SKU detail desired, the more complex and expensive will be the pertinent processes.

Information Requirements for Staple-Stock Inventory Management

Basic Premises. Let us explore the information requirements for staple-stock inventory management. As discussed earlier, the life cycle for the bulk of staple merchandise is of relatively long duration, with very few sudden and sharp shifts in demand, exclusive of seasonal factors. Transferring such goods between different selling units is not a normal procedure, since these items can be carried in the original selling outlet to which assigned for a lengthy period of time and still be sold at the original markup. Furthermore, due to the stock maintenance policy of vendors and the rapid rate in which they normally replenish the retailer's inventory, those responsible for retail inventory management need not concern themselves too much with whether merchandise will be available when needed. They can proceed on the assumption that it will. As a consequence, the major thrust of reporting programs for staple-stock inventory management can be focused upon (1) formulating and revising model stock levels for each SKU, (2) ensuring that replenishment occurs expeditiously and in accordance with the rates of sale and the forecast models, and (3) establishing merchandise reordering procedures to be as automatic a process as possible, perhaps making this a computer-delegated function.

Warehouse and Store Level Stock. Retail stores, particularly chain stores, which maintain their own warehouse will be concerned with staple-stock inventory management of a two-fold nature. Proper control must be maintained over stocks at both the warehouse and individual store level. In the case of food chains, for example, the amount of inventory investment that is found in the stores may exceed by three times that for the warehouse, although the latter investment may be in itself a very substantial sum. Thus, a well-functioning inventory management system between the warehouse and the store's vendors may be largely negated if poor controls are exercised at the store operating level.

Guidelines for Staple-Stock Inventory Systems. The following set of guidelines should direct the formulation of manual or computerized inventory-management systems for staple stock:

1. The desired rate of service level should be provided. This can mean either of the following: Ensuring that when a customer comes to a store to purchase an item, it will be available in the price, color, size, etc. that is desired a designated percentage of the time, be it 80, 95, or 98.5 percent. Or, guaranteeing that when a selling outlet requests replenishment from the retailer's warehouse, the item needed will be available for shipment to the store a certain percentage of the time. As would be expected, the higher the service level sought at the store or warehouse stratum, the greater will be the average inventory investment. At times, the realization of the heavy inventory investment necessitated to achieve a particular service level may produce a downward revision in what is deemed a satisfactory percentage.

2. The average inventory investment should be kept to a minimum. This should occur, of course, within the parameters of the prior establishment of a service level that is considered economically feasible and sufficient to maintain a strong competitive position. Thus, the objective is to attain the desired service level alongside an optimum inventory turnover. Among certain well-managed food chains, an annual inventory turnover of 22 times, as well as a service level in the retail stores of 98 percent, is not an unreasonable expectation for many items via sophisticated computer information programs.

3. The costs associated with the maintenance and handling of the stock, such as labor, inventory taxes, inventory obsolescence, and shrinkage, and the costs of processing the vendor purchase orders and the store replenishment requisitions should be kept to a minimum. A true realization of these expense factors can often modify policy considerations relative to the above two-mentioned factors.

Decision Parameters. Within the framework of the above-stated guidelines, three basic decision-parameters are to be established:

1. When to order (order point determination) — At what point should a store forward a requisition to the warehouse for inventory replenishment, or the warehouse send a purchase order to the vendor? To what level can the stock-on-hand level fall before these steps are initiated? Factors influencing these decisions would include the amount of safety stock, the rapidity with which the required paperwork can be facilitated, and the vendor's lead time (the interval between the time that the requisition or purchase order is sent out and the actual receipt of the merchandise).

2. How much to order (order quantity determination) — How much replenishment merchandise should be requested by a requisition or a purchase order? This is affected by quantity discount considerations and transportation rates for varying size shipments. Also important is the minimum pack size that a resource will ship to a retailer, as well as the minimum pack size that can be processed and handled economically between the store's warehouse and its selling units.

3. How much safety stock (safety stock determination) — The degree of service level desirous of attainment will have to be maintained at the store and warehouse level. The higher the service level sought, the greater will have to be the safety stock in view of the possible snags that may develop within the reordering process.

Illustration of a Staple Stock Report. Table 4 is an example of a computerized report effected by some chains for staple-stock inventory management at the individual store level. It not only provides important information to the store manager and his assistants, but also provides computer formulated guidelines for shelf allocation and reorder points for each SKU on this system. These latter variables are influenced by the rate of sale of each item, and the percentage gross profit and weekly dollar profit. Periodically, revisions are made by the system to facilitate a more profitable emphasis upon inventory replenishment and self allocation.

TABLE 4. INVENTORY MOVEMENT REPORT — STORE 10

Item No.	Item Description	Pack Size	History-Weeks	Total Units Sold	Average Weekly Units Sold	Profit (%)	Weekly Profit ($)	Shelf Allocation	Reorder Point
465432	XXXXX	24	22	216	9.81	41.8	0.90	34	10
478411	YYYYY	24	23	888	38.60	32.1	2.80	63	39
567487	ZZZZZ	24	23	1416	61.55	30.9	3.96	86	62

Information Requirements for Fashion-Goods Inventory Management

Basic Considerations. The information requirements for fashion-goods inventory-management are of a somewhat different nature than for staple items. As discussed earlier, the life cycle for most fashion items tends to be relatively shortlived, and is prone to unpredictable rapid upward and downward shifts in demand. Moreover, a particular item may have a sharply varying demand pattern from one outlet to another of the same retail chain, even within the same metropolitan area. Thus, for instance, a new women's handbag may sell well in black in some units, while faring poorly in the remainder. Quick corrective action is required if the bulk of the handbags are to be sold within the time span permitting full-markup pricing.

The aim of information systems for fashion goods is to provide pertinent data as rapidly as possible, and in the proportion of detail conducive to easy comprehension and interpretation. Timeliness is of critical importance in view of the rapid depreciation that may occur in unsold stock, and the limited opportunities for replenishment from vendors. A continuum of personal subjective judgements as contrasted to a strong reliance upon predetermined statistical formulas for inventory-management guidance is a necessity, in view of the ordinary unfeasibility of one-to-one replenishment for fashion goods. Under the existing state of computer arts, computerized automatic reordering-systems as are presently operative for staple goods are not a realistic alternative for fashion merchandise. However, it should be noted that computer-generated recommendations for inventory-management decision-making in fashion lines, which are then subject to human review and modifications, are presently under experimentation in some stores. Time will disclose whether fashion goods can be made subject to many of the same sorts of computer systems disciplines as staple commodities.

Electronic Data Processing (EDP) Reports for Fashion Goods Control. At this point, let us examine the types of EDP reports in vogue for fashion goods control, and the types of benefits that retailers can garner from them.

1. Stock-on-hand [all stores (consolidated) and individual outlet] — Some EDP reports produced by advanced computerized systems supply stock-on-hand status and unit sales by SKU for fashion departments. The data are provided both on an all-stores basis, and by individual selling unit. These information flows are supplied as a rule once a week or twice a month. They enable a ready discernment by those responsible for inventory management as to those outlets in which particular SKUs have become depleted due to strong consumer acceptance, and, conversely, to those units in which an overstocked situation is occurring due to poor customer reaction to the merchandise. It is not uncommon to use such data to transfer fashion goods from stores in which they are moving slowly to those where demand is strong to preclude taking markdowns in the former establishments. Sales and stock-on-hand data by individual outlet indicate stores for which replenishment from vendors is desirable, as well as facilitating remedial stock balancing to compensate for defective initial distribution of goods.

2. Sales — full status report [all stores (consolidated) and individual outlet — More typically available computerized data-flows for fashion goods are reports providing only dollar and unit sales by SKU on a departmental basis. The stock-on-hand position must be calculated manually by those responsible for inventory management. Sales are reported for all items on this reporting system, with data issuance occurring usually as frequent as two or three times per week. In some firms, it takes place on a daily basis. Those responsible for inventory management can perceive the relationship of sales performance to plan, enabling more timely response on a companywide and individual outlet basis.

3. Sales (best sellers) — Retailing differs from manufacturing in that the latter usually involves the production of large quantities of a small number of models or styles. Retailing, on the other hand, particularly for fashion goods, concerns the purchase and sale of a few units each of a numerous quantity of styles. As a result, computerized reports providing sales and stock-on-hand data for all of a department's SKU's can appear to their users as a veritable maze of statistics. Some retail firms have effected exception reports to facilitate a more meaningful discernment of just those transactions necessitating more pressing attention. One such highly useful control mechanism for inventory management is the best-seller report, which provides data just for those items that are experiencing a superior rate of sale, as compared to the norm for that department. The quicker such development can be noted, the more expeditiously can reorders be forwarded to the vendors. Rapid reordering is expecially critical for fashion goods, since many manufacturers engage in only a limited production run, which, when depleted, will not be repeated in any way.

4. Sales (slow sellers) — Another valuable exception tool is the slow-seller report, which lists those fashion items selling at a below normal pace for the merchandise department. Where slow-selling styles can be rapidly detected and the pertinent vendors so informed, some manufacturers will reclaim the merchandise and forward it to other retail concerns where the fashion is successful. In those cases where such a solution does not present itself, a retailer may elect to take a rapid but modest markdown, in hope that a quick response of this nature will preclude the need for a steeper price reduction at a later date.

5. New receipts report — In view of the fact that many fashion items experience a relatively short life cycle during which profitable sales can be realized, it is important to know if goods have been received from vendors when scheduled. A computerized new receipts report provides these data. It also indicates if merchandise substitutions were made by the manufacturer. A quick attainment of this information enables a quicker follow-through with errant vendors. Furthermore, the new receipts report enables those involved in inventory management to assess more readily the actual open-to-buy status of the department.

6. Vendor analysis report — A computerized representation of all vendors from whom departmental purchases were made, in which a comparison is made of their respective performance relative to sales, markup, markdown, inventory turnover and promotional allowances can be a valuable control mechanism. A broad range of computerized data about relative

manufacturer contribution to departmental profitability can be substituted for previously relied-upon subjective opinions, or semicomplete information that is manually derived. Computerized vendor analyses are of particular value when stores are negotiating with manufacturers for price, promotional, delivery, and other forms of concessions. Vendors will generally accept the validity of computer reports shown to them. This contrasts to their frequent dubious attitude toward verbal or manual-report representations from retailers which attempt to demonstrate how one manufacturer fared relative to another. Few resources believe that computerized vendor analyses of retailers would be manipulated to prove a particular point.

Information Requirements for Big Ticket Inventory-Management

Selling Methods and Information Needs. Few customers are in a position to take big ticket items home with them upon making a purchase in view of the size and bulk of such merchandise. Also, as mentioned earlier, most sales of big ticket items are made via floor samples. The goods that are subsequently shipped to the customer either are available in the retailer's warehouse at the time of sale, or else they are obtained by the retailer placing a special order with the manufacturer.

In view of the different nature of big ticket merchandising, computerized information systems that are formulated should enable the retailer to have the following data capability:

1. Provide information at the time of customer request as to whether the particular item wanted is available in the warehouse; if it is on order and the expected arrival date from the manufacturer; or if a special order must be sent to the vendor, what will be the anticipated delivery time. Weekly computerized reports, for example, can be sent to each store containing such information for salesmen usage. Or, a superior and more advanced system would be to have a terminal in each store permitting direct inquiry of the files containing these data, thereby giving the most up-to-date knowledge. Some furniture chains already have implemented this latter approach.

2. Supply information as to where a particular item is situated in the warehouse. A thorough system of this type, which allows immediate tracing of an item, makes feasible the storage of merchandise in the warehouse on a random spot-available basis; i.e., putting any good in any portion of a warehouse depending upon the space that is available at the time of receipt from the manufacturer. This permits the most economical utilization of warehouse space.

3. Permit the immediate reservation of an item in the warehouse upon its sale to a customer so that it won't be resold erroneously to another customer at a later time.

4. Provide those responsible for inventory management with reports indicating late shipments from vendors. Doing so will permit the salespeople to inform the customer awaiting an item. This will preclude many angry customers calling the store on their own and cancelling a late shipment. Also, such information will enable retailers to determine accurately which vendors are consistently late in their shipments, and which produce cancelled sales to the store.

5. Provide a capability to change delivery instructions, based upon new instructions supplied by a customer after the purchase has been transacted. This will ensure that the item is forwarded to the customer at the time it is wanted for delivery. Much customer good-will has been lost due to delivery at the wrong time; i.e., from the purchaser's point of view.

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